ASTRONOMY,

AS IT IS KNOWN AT THE PRESENT DAY.

TO WHICH IS ADDED,

A SUPPLEMENT,

CONTAINING AN ACCOUNT OF THE

Nature of Astronomical Instruments.

THE MANNER OF CALCULATING

THE NOTES OF THE CALENDAR,

THE DISTANCES AND MAGNITUDES OF

THE PLANETS,

AND A NUMBER OF OTHER USEFUL AND INTERESTING

CALCULATIONS IN ASTRONOMY.

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PREFACE

THERE is no science in which progressive improvement is so distinctly marked as in Astronomy. The steps by which it has advanced to the state of excellence in which we now behold it, may be as accurately traced as the principal events of our past lives. But although this be the case, and although the improvement of this science has been productive of more important benefits to society than any other that could be named, yet there is no branch of useful knowledge so little studied by the inhabitants of this country, at the present day, as Astronomy. For though great and important discoveries have lately been made in this science, yet a knowledge of these and even of the principles of the science itself, is confined to a few individuals. The chief reason, perhaps, that can be assigned for this well known fact, is, that the science of Astronomy has been generally cultivated by eminent mathematicians, and hence an ill-founded opinion has arisen, that it is necessary to study a tedious course of *mathematics*, previous to entering upon the study of this science. But however necessary mathematical knowledge may be in the pursuit of astronomical studies, much important and useful information may be acquired on this subject, without possessing a knowledge of mathematics.

CONTENTS OF THE SUPPLEMENT

Astronomy,

AS IT IS KNOWN AT THE PRESENT DAY.

ON THE UTILITY OF ASTRONOMY.

ASTRONOMY is one of the most ancient and one of the most pleasing branches of knowledge which has ever engaged the human mind. The grandeur and sublimity of the objects it presents elevate and improve the mind, banish low and frivolous passions, and become a source of never-ceasing pleasure.

No species of knowledge that is attained by the light of nature, gives higher or juster notions of the Supreme Being; no science affords stronger arguments by which his existence is demonstrated; and none gives more convincing proofs of HIS power and wisdom; for, as David says, "the heavens declare the glory of God, and the firmament sheweth his handy work."

Cicero, who was guided only by the light of reason, appears to have had the same sentiments; for "nothing," says he, "is more evident, nothing is plainer, when we look up to the heavens, and contemplate the celestial bodies, than that there is a Deity of most excellent wisdom who governs them.'

For the certainty and evidence of its demonstrations, Astronomy is not inferior to Geometry: the motions of the heavenly bodies being now as certainly known, and their causes as strictly demonstrated, as any proposition in pure Mathematics.

The smallest stars we can see, though at an immeasurable distance from us, have their latitude and longitude as exactly determined as any place on the earth; and the eclipses of the sun and moon, the conjunctions, oppositions, and phases of the planets, are calculated with the greatest precision.

"There is no science," says Dr. Keil, "in which there remains fewer difficulties to be explained, objections to be answered, or scruples to be removed, than in Astronomy, and no science has attained so high a degree of perfection as it has; for no philosopher has ever yet discovered the figure of the small particles of matter, or the texture, intervals, form, and composition, of the parts of the most common plant."

Nor has any Physician yet discovered the reason of the virtues and operations by which his medicines affect the human body. And

in all ANIMAL and VEGETABLE bodies, the fountain and first principle of LIFE and ACTION are unsearchable, and look like a mystery far beyond the reach of our understanding, and perhaps may for ever remain unknown to us.

But Astronomers (in their proper sphere) meet with no such difficulties, for it is no part of their business to contemplate the nature of the celestial bodies; but their motions, their magnitudes, and the various phenomena arising from their motions.

They not only determine what sort of motions the PLANETS have, how large orbits they describe, and how long they take to complete their revolutions, but they likewise show the crooked tracts in the immense regions of space which the wandering Comets describe, and give us the geometrical dimensions and properties of their orbits, and the laws they observe in describing them.

Astronomy has at all times been studied by the greatest philosophers and men of genius in every part of the world; and the most celebrated of the ancients speak of it with admiration. When Anaxagorus was asked for what end he was born, he answered, "To contemplate the Stars." If there is much enthusiasm in this reply, we at least see with what admiration a man of genius contemplated the sublime spectacle of the heavens.

Plato had also the highest regard for this science; for in his work, entitled "Epinomis, or the Philosopher," he says, "that no wise man would be ignorant of Astronomy."

This science not only contributes to the improvement of many other sciences, but it is also of admirable use in strengthening the mind, and arming the reason against the effects of ignorance and superstition.

Every one must allow that morals would be quite vague, and have but few attractions, if founded on ignorance or error. Ought it then to be accounted of no value, to have the advantage of being preserved from the fatal effects arising from this cause?

Can we look without the emotions of compassion and pity on the stupidity of those, who believed that by making a great noise during the time the Moon was *eclipsed*, that it gave relief to her sufferings, and freed her from the disease with which she was supposed to be afflicted, and which they believed to be produced by enchantment?

Besides these errors, which degraded the human mind, we find in history many passages which show the FATAL EFFECTS arising from the ignorance of this science.

Nicias, the Athenian general, had resolved to quit Sicily with his army; but an Eclipse of the *Moon* made him lose the favourable opportunity, which was the cause of the death of the general, and the ruin of his army. This disaster was so fatal to the Athenians, that the decay of their country immediately followed it.

Alexander the Great was so afraid of an Eclipse of the Moon before the battle of Arbella, that he ordered sacrifices to be offered to the moon and to the earth, as to divinities that caused the eclipse.

On the contrary, we have many examples of those who possessed a knowledge of Astronomy, turning that knowledge to the greatest advantage, both to themselves and to their country.

When Pericles commanded the Roman fleet, there happened an Eclipse of the Sun, which caused a general terror throughout the fleet, even the PILOT himself was afraid.

Pericles, however, knew the true cause of the phenomenon, and reasoned with the Pilot in a very familiar manner; he took the end of his mantle, and after covering the eyes of the Pilot with it, said to him, "Do you believe that what I now do is a sign of misfortune?" "*No*," said the Pilot. "This is an Eclipse to YOU," said Pericles, "and it differs nothing from that which has just happened, except in this, that the Moon being larger than my MANTLE, hides the Sun from a greater number of persons."

Agathocles, king of Syracuse, while engaged in a war in Africa, found terror spreading through his army at the sight of a Solar Eclipse, he immediately presented himself to his soldiers, and explained the *cause* of the phenomenon, which had the effect of dispelling their fears, and restoring order

Many other examples of the application of astronomical knowledge may be brought from history; but those already mentioned may serve to show the usefulness of Astronomy, even in affairs apparently nowise connected with it

The story of Columbus and the natives of Jamaica, is too well known to require to be noticed here

The knowledge of Astronomy has also been of great advantage in exposing the absurdities of *Astrology*, and freeing men's minds from that species of deception to which they were so long the dupes. In the year 1686, all the Astronomers in Europe agreed in announcing to the world a conjunction of all the Planets then known, which they said would be accompanied with such dreadful effects, that there would be great danger of a general overthrow, and every person expected to see the end of the world That year, however, passed as others had done before it, but a hundred other false predictions were not sufficient to free the ignorant and credulous from the prepossessions and prejudices of their infancy. It was necessary that a spirit of philosophy and research should spread among men, that the extent and limits of NATURE should be unfolded to them; and accustomed no more to fear without examination, and without proof; yet we still see, from time to time, the credulity of the public, in listening to the reveries of ignorance and superstition. So late as the year 1736, when there happened a very extraordinary HEAT, and furious wind, on the 20th October, it was published in all the Gazettes that the Sun had returned, or gone back to the tropic of Cancer. This was so generally believed, that it became necessary for the learned to take the trouble of undeceiving the public. About the end of the year 1768 too, every person believed the Planet Saturn lost; and it was even published in the most sensible periodical publications, and talked of in the most cultivated companies.

Comets were, above all, one of the greatest objects of terror; but a knowledge of Astronomy has shown these fears to be groundless, and has even dispelled them from the minds of the most ignorant.

But it is not only in this way that Astronomy has rendered itself useful: it has been serviceable to mankind in many different ways. It is well known that Geography and Navigation are so intimately connected with Astronomy, that they cannot be separated, and that all the improvements and discoveries in these branches of knowledge are entirely owing to the science of Astronomy.

The observation of the altitude of the Pole Star, first taught men that the Earth was round; and Eclipses of the MOON first served to make known the Longitude of places. "We should not know," said Hypparchus, "whether Alexandria be to the North or South of Babylon, without the observation of Climates; and we cannot know whether a country be East or West of another, without the observation of Eclipses."

We find also by the Alcoran, that travellers in crossing the desert of Arabia took certain *stars* for their guides; for it is there said, that "God has given you the stars to serve you as guides, whether you be upon the land or the water."

The discovery of Jupiter's Satellites has given greater perfection to our geographical and marine charts, than could have been done for a thousand years by voyages and travels; and when their theory shall be rendered still more complete by multiplied observations, the method of finding the longitude will be both more easy and more accurate.

The improvements which have been made in geography since accurate observations began to be made in Astronomy, will be best understood by mentioning an example or two.

The length of the Mediterranean Sea was unknown till the beginning of the seventeenth century, but is now as well known as the length of Great Britain.

The difference of Longitude between Cairo, and Toledo in Spain, is stated, in the geography of Gemma Trisius, (published 1530,) to be 53° instead of 34° 30′; and other distances are exaggerated in the same manner.

Till the year 1769, there were three or four degrees uncertain on the length of the CASPIAN and BLACK Seas; and before the same year there was an error of half a degree in the Longitude of Gibraltar.

America was unknown till the year 1502; and its discovery is solely to be attributed to the knowledge of Astronomy possessed by Columbus.

It appears he had an intimate acquaintance with the doctrine of the Sphere, which gave him that confidence which prompted him to direct his course to the westward, certain of either coming on the vast continent of Asia, or of discovering a new one. If any thing yet remains for the improvement and security of navigation, it is an easier and more expiditious method of finding the longitude at sea.

There is at present a method of performing this with great accuracy, by means of measuring the distance between the sun and moon, or the moon and a star; and if seamen knew a little of Astronomy, they never could be deceived above ten leagues, whilst they are sometimes more than 200 uncertain, on ordinary voyages, such as going to America and the West Indies.

The uncertainty that Lord Anson was in, respecting the situation of the island of Juan Fernandez, made him keep the sea much longer than would have been necessary, had not this been the case, which might have saved the lives of seventy or eighty of his men. But accidents even more fatal than this have been occasioned by errors of a similar kind.

The advantages of navigation to the success of a nation prove in a very convincing manner the usefulness of Astronomy.

The trade and prosperity of Great Britain, as well as her success at sea in war, shows that the Navy alone can decide the fate of Empires and give to a nation both wealth and power; for, as M. le Meire says, "The TRIDENT of Neptune is the Sceptre of the world."

Agriculture formerly borrowed from Astronomy most of its rules and indications; for Job, Hesiod, Veron, Eudoxus, Aratus, Ovid, and Pliny, furnish us with proofs of this; the HELIACAL rising or setting of the Pleiades, of Arcturus, Orion, and Sirius, gave to the Greeks and Egyptians the signal for different kinds of work.

For example: the rising of Sirius announced to the Greeks the time of harvest, and to the Egyptians the overflowing of the Nile.

Ancient Chronology receives, from the knowledge and calculation of Eclipses, the *most certain* points, or epochs, that it is possible for us to have. The Chronology of the Chinese is all founded on Eclipses of the Sun and Moon; and if there had always been Astronomers in the world, there would be no uncertainty in the date of any remarkable event mentioned in history.

It is by an Eclipse of the Moon that an error has been discovered in the date or commencement of the Christian era, or birth of Jesus Christ. We know that Herod was king of Judea; and we are informed by Josephus, that there was an Eclipse of the Moon immediately before the death of Herod. Now we find that this Eclipse happened in the night of the 12th or 13th of March, four years before the commencement of the vulgar era; therefore that era ought to be put back three years at least.

It is also by knowing that an Eclipse of the Sun can only happen at the time of NEW MOON, and that he can only be totally eclipsed for a few minutes (7½), that Christians are convinced that the darkness which took place at the crucifixion of Jesus Christ was supernatural; for this event took place at the time of the Jews' PASSOVER, which was kept at the time of FULL MOON.

It is likewise by means of Eclipses of the Sun, that Castor fixed the termination of the war between the Lydians and Medes to the

year 603 before our era; and the expedition of Xerxes against Greece to the year 478, which is commonly fixed to 480 before our era. Sir I. Newton too has made use of Eclipses in settling the dates of many disputed parts of Grecian history. Abbe Barthelemy has likewise employed the same means to settle some uncertain dates which occur in the history of Greece.

Another important use of Astronomy is, to furnish us with the means of dividing time, and of regulating our clocks and watches, which is a matter of much greater importance than many are aware of; for the multitude of our affairs, and the necessity for exactness in most of them, have rendered accuracy in the division of time absolutely necessary. Now this cannot be accomplished any other way than by comparing the motion of our timekeepers with the motions of the celestial bodies.

Meteorology, or the knowledge of the changes of the air, such as winds, rains, droughts, &c. have certainly a very material and immediate effect on the state of the human body. It is, therefore, highly probable, that Astronomy would be of very great use in determining these effects, if we could discover the physical influence of the Sun and Moon on the atmosphere, and the changes produced in that fluid by those bodies. It is well known that the Moon not only raises the waters of the ocean twice every day, but that she has considerable effect on the state of the atmosphere. This has led several eminent physicians, such as Mede, Hoffman, &c. to believe that there may be some connection between the Moon and medicine; but whether this be the case or not, it is well known that the state of the weather has a very material effect on the human body.

"But," as Fontenelle says, "though astronomy should not be absolutely necessary for the purposes of geography, navigation, and even for the cultivation of divinity, yet it is highly worthy of the attention of every rational being, for the noble and sublime spectacle which it presents to the mind."

"There are," says the same author, "in some deep mines many poor ignorant creatures who have been born there, and have even lived and *died* there, without ever once having seen the Sun." Such is nearly the condition of those who are ignorant of the nature, order, and course of those glorious orbs, which roll above their heads, to whom the greatest beauties of the heavens are unknown, and who have not light enough to enjoy the universe.

To those who love the writings of the ancients, whether historians or poets, a knowledge of astronomy will be found extremely useful. Since it is proved that all the mythology of antiquity took its rise from astronomical symbols and allegories, and that the writings of the ancients abound with allusions to these symbols and allegories, it is evident that an acquaintance with astronomy is necessary, in order to understand these writings.

The poets who have described Greece and Italy, and whose works are sure of immortality, all loved and knew astronomy. Some

of them have even made so frequent use of it, that it is impossible to understand their works without possessing some acquaintance with astronomy. Among the Greeks who have introduced this subject into their writings, may be mentioned Homer, Hesiod, and Aratus; among the Latins, Lucretius, Horace, Virgil, Lucian, Menelaus, and Claudien. The particular passages it is unnecessary to mention, as every one who looks into these authors will find many passages of this description.

The knowledge of the heavens has often been the source of many beauties in the works of the ancients, and we rarely find among them that strange ignorance of astronomy, which disgrace some modern works.

The respect that has always been paid to celebrated astronomers in every country where they have appeared, is a very convincing proof of the high esteem in which this science has always been held.

The ancient Kings of Persia, and the Prætors of Egypt, rank among the greatest of the ancient astronomers. The Kings of Lacedemon kept astronomers in their councils, and Alexander the Great had them in his suit in all his military expeditions; and we are informed by Aristotle, that he would do nothing of moment without their advice. It is true, that the taste for predictions was carried too far by the astronomers of those days; but true astronomy profited very much by their labours.

It is well known how much Ptolemy Philodelphus the Second, King of Egypt, favoured astronomy; and we find that in his time there flourished many celebrated astronomers, among whom were Hypparchus, Apollonius, Aratus, Bion, and Theocritus.

Julius Cæsar piqued himself very much on his knowledge of astronomy; and we see by his reformation of the calendar, that he was well acquainted with the subject.

We find also that the Emperor, Claudius Cæsar, was well acquainted with astronomy, for he calculated an eclipse which was to happen on the anniversary of his birth; and fearing that it would occasion at Rome consternation, and perhaps tumult, he published an advertisement, in which he explained the causes of such a phenomenon.

Many other princes might be mentioned who have cultivated astronomy; such as Adrian, Constantine, Charlemagne, Leon the Fifth, &c; but these will be noticed in treating of the improvements and discoveries which have taken place in this science at various periods.

EXPLANATION OF ASTRONOMICAL TERMS.

PREVIOUS to entering upon a description of the motions and appearances of the various bodies that are to be seen on turning our eyes to the heavens, it may be necessary to give a short explanation of some of the terms which most frequently occur in Astronomy,* in order that the reader may be the better enabled to understand what follows.

1. A *Sphere*, or Globe, is a solid body, perfectly round, or having every part of its surface equally distant from a point within it, called its centre.

2. The *Diameter* of a Sphere is any straight line passing through the centre, and limited on each side by the surface of the sphere.

3. The *Radius* of a Sphere, or Circle, is half the diameter.

4. The *Circumference* of a Sphere, or Circle, is the line which goes quite round it.

5. A *great* Circle divides the surface of the sphere into two equal parts, or hemispheres.

6. A *small* Circle divides the sphere into two unequal parts; the one greater, and the other less than a hemisphere.

7. The *Plane* of a Circle is the surface or superfices contained within its circumference, as the level or flat surface which would appear on cutting a sphere through, at any circle drawn upon it. This surface, extended or continued to any distance beyond the circumference of the circle, would still be in the plane of the circle.

8. *Degrees, &c.*—All circles, whether great or small, are supposed to be divided into 360 equal parts, called degrees; each degree into 60 equal parts, called minutes; and each minute into 60 equal parts, called seconds, &c.†

9. An *Angle* is the inclination of two lines which meet in a point, and is always some part of a circle; that is, contains a certain number of degrees, minutes, &c.

10. A *Right Angle* is the fourth part of a circle, or 90°, and is formed by making one line perpendicular to another.

11. An *Acute Angle* is less than a *right* angle; and an Obtuse one is greater.

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* The present work being of a popular nature, it is only necessary to explain here such terms as occur in the following pages.

† Degrees are always marked thus (°), minutes (′), and seconds (″).

12. A *Rectilineal Angle* is an Angle which is formed by straight lines; and a Spherical Angle by curve lines. Most of the angles connected with astronomy are spherical angles.

13. The *Equinoctial* is a great circle in the heavens, equidistant from both poles, and right over the equator of the earth.

14. The *Ecliptic* is that great circle in the heavens, in which the earth performs its annual revolution round the sun; half of it being on the north side of the equinoctial, and the other on the south.

15. The *Obliquity of the Ecliptic* is the angle formed by the intersection of the equinoctial and the ecliptic; at present this angle is 23° 27′ 46″; but it is subject to a small change. Since it was first observed it has been diminishing at the rate of ·52 in a century.

16. The *Equinoctial Points* are those two opposite points in the heavens, where the ecliptic and equinoctial cross each other.

17. The *Zenith* is the highest point of a sphere, or that point of the heavens directly over the head of the spectator.

18. The *Nadir* is that point of the heavens directly opposite to the Zenith, or under the feet of the spectator.

19. The *Zodiac* is a zone, or belt of about 16° broad, which surrounds the heavens; and in the middle of it is the Ecliptic, or orbit of the earth. It also includes the orbits of all the planets, except those discovered since the year 1800.

20. The *Precession of the Equinoxes* is a change of the equinoctial points. These points are found to move backwards 50¼ seconds every year, or one degree in 72 years; so that in about 25,920 years, they return again to the same points in the heavens, performing what is called the grand Celestial Period. The retrograde motion of these points is caused by the action of the sun and moon upon the earth, in consequence of its spheroidical figure.*

21. *Meridians* are great circles in the heavens, perpendicular to the equinoctial, and passing through its poles.

22. The *Horizon* is that great circle which is equally distant from the zenith and nadir, and which divides the visible from the invisible hemisphere. This is called the Rational Horizon, to distinguish it from the Sensible Horizon, a *small* circle which terminates the view of the spectator, when placed at any point of the earth's surface.

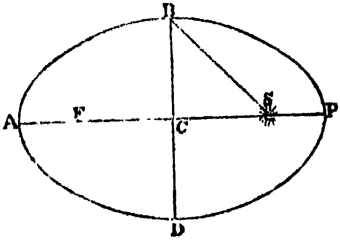
23. *Vertical* Circles are great circles which pass through the zenith and nadir, and cut the horizon at right angles.

24. The *Altitude* of a Celestial Body is its height above the horizon, reckoned on the vertical circle which passes through it; and its *meridian* altitude is the altitude when it is on the meridian.

25. The *Parallax* of any celestial object is the difference of its angular position as it *would be seen* from the centre of the earth, and as it *is seen* from a point on the surface of the earth. This is called the *diurnal parallax*, to distinguish it from the *annual parallax*, which is the difference between the apparent places of an object in the heavens, when seen from the earth in opposite points of its orbit.

* The motion of these points backward, makes the fixed stars appear to move forward an equal quantity, their longitude and right ascension being reckoned from one of those points, which is called the vernal equinox.

26. The Orbit of a Planet or Comet is the path or tract in which it performs its revolution. The orbits of all the primary planets are elliptical or oval, with the sun situated in one of the foci, as at S.*



When the planet is at P, it is then nearest the sun, and is said to be in its *Perihelion*. In moving from P, its distance from the sun gradually increases till it reaches the opposite point A, when it is at its greatest distance from the sun, and is then said to be in its *Aphelion*. When it arrives at the points B and D, it is at its mean distance.

The straight line A P, which joins the perihelion and aphelian, is called the line of the apsides, and sometimes the greater axis of the orbit; and the line B D, which joins the points of mean distance, the lesser axis; the line S B or S D the planet's mean distance from the sun; S C or F C the eccentricity of the orbit, or the distance of the sun from its centre; S the *lower* Focus, or that in which the sun is placed; F the *higher* Focus; P the *lower* Apsis; and A the *higher* Apsis.

27. Although the Primary planets have all nearly the same common focus in which the sun is situated, yet they have not all the same degree of ellipticity. Most of them deviate but little from the circular form, and none of them so much as the above figure. They likewise lie in different or planes, make angles with each other.

28. If the *Ecliptic*, or earth's Orbit, be supposed to be a thin solid plane extended in every direction, it would be called the plane of the ecliptic; and if the orbit of any other planet were extended in a similar manner, it would be called the plane of that planet's orbit. Now the orbits of all the planets lie in planes different from that of the ecliptic; and this difference, or the angle which any orbit makes with the ecliptic, is called the *inclination* of that orbit.†

One half of each orbit is on the one side of the ecliptic, and the other half on the other side; consequently it must cross the ecliptic in two

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* If the two ends of a thread be tied together, and thrown loosely over two pins stuck in a table, as S and F, and if the thread be moderately stretched by the point of a pen, or black-lead pencil, and carried round the pins by an even motion, and slight pressure of the hand, an ellipsis or oval will be described; and the points S and F, where the pins were fixed, are called the foci, or focuses of the ellipsis. The figure described will be the more elliptical, the tighter the thread is to the pins in the foci.

† The orbit of Mercury is inclined 7° to the plane of the ecliptic; Venus 3° 23′; Mars 1° 51′; Jupiter 1° 19′; Saturn 2° 30′; Uranus 0° 46½′; Ceres 10° 37′; Pallas 34° 50′; Juno 21°; and Vesta 7° 9′. The orbits of the first five of these, as well as that of Uranus, or what are called the old planets, are all included in the Zodiac; but the orbits of the last four, or the new planets, are without the Zodiac.

opposite points. These points are called the planet's *nodes*.* These nodes are all in different parts of the ecliptic; and therefore if the planetary tracts remained visible in the heavens, they would in some measure resemble the different ruts of waggon-wheels on a road, after crossing each other but never going far asunder.

29. While the primary planets are performing their revolutions round the sun, and the secondaries round their primaries, they have all a motion from west to east, round an imaginary line passing through their centre, called their *axis*. In some of the planets this axis is nearly perpendicular to the plane of its orbit; and in others it is inclined to the plane of its orbit. On this depends the change of seasons in the planet; for the smaller the angle which the axis of any planet makes with the plane of its orbit, the greater is the variety of its seasons.

30. The extremities of the axis is called the poles; and that which points towards the northern part of the heavens is called the *north pole*; and the other, pointing towards the southern part, is called the *south pole*.

31. As it is necessary to have some method by which the position of any celestial body may be determined at any time, or its distance from some known point, astronomers have fixed on the ecliptic for this purpose, as well as for reckoning from it, the inclination of the planetary orbits.

The line of the equinoxes, or that line which joins the equinoctial points, being always in the plane of the ecliptic, must mark out two points of that line traced among the fixed stars; and from one of these points astronomers reckon distances on the ecliptic. This point is called the vernal equinox, because the sun appears in it in the spring, about the 20th of March; its opposite is called the autumnal equinox, because the sun arrives at it about the middle of autumn, or the 23d of September.

32. The *Ecliptic* is supposed to be divided into twelve equal parts, called signs, each of which occupy a space of 30 degrees.

33. The *Longitude* of all the celestial bodies is reckoned eastward, on the ecliptic, from the vernal equinox quite round the heavens, and consequently may amount to nearly 360 degrees.

The *Latitudes* of the celestial bodies is reckoned from the *ecliptic*, north and south; but their *declination* is reckoned from the *equinoctial*, in a similar manner.

34. The *Right Ascension* of the celestial bodies is reckoned on the equinoctial, from the *vernal* equinox, eastward, quite round the heavens.

35. Instead of the Vernal Equinox, astronomers sometimes find it convenient to count the distance of a *planet* from its *aphelion*, (as from A, in the foregoing figure.) This distance is called the true anomaly of the planet.

36. An imaginary line, drawn from the sun to a planet, in any point of its orbit, as S B, is called the *radius vector*, or great radius. This line has the property of describing equal areas of the orbit, in equal portions of time.†

37. The *Elongation* of a Planet is its angular distance‡ from the sun, as seen from the earth

* The node, where the orbit ascends above the ecliptic, is called the ascending node; and the other the descending node.

† This was discovered by Kepler, and is called his second law.

‡ By angular distance is meant any distance in degrees, minutes, &c.

38. The *Opposition* of two celestial bodies takes place when they are in opposite points of the heavens, as viewed from the earth; and their *Conjunction* when they appear in the same point. These points are also sometimes termed the syzygies, especially when the bodies are the sun and moon; And when a planet is between the sun and the earth, at the time of conjunction, it is called its *inferior* conjunction; but when the sun is between the earth and the planet, it is called its *superior* conjunction.

39. The *Geocentric* Place of a Planet, means its place as seen from the earth, and its *Heliocentric* place as seen from the sun.

40. The *Direct* Motion of a Planet is its motion in the order of the signs, as from Aries to Taurus, &c.; when it moves in a contrary direction, it is said to have a *retrograde* motion.

41. The *Occultation* of a Star or Planet is its obscuration by the moon, or other planet, coming between it and the earth.

42. By the *Sidereal* Revolution of a Planet is meant the time it requires to move from any fixed star to the same again.

43. The *Disc* of the Sun, or a Planet, is its face, which appears flat on account of its immense distance.*

44. *Aberration* is an apparent motion or change of place in the heavenly bodies, occasioned by the progressive motion of light, combined with the earth's annual motion in its orbit.

45. *Nutation*, or Deviation, is a small inequality which has been observed in the precession of the equinoxes, which makes the fixed stars appear to change their positions about 9″ of a degree.

46. *Evection* is an inequality in the motion of the moon, by which at or near the time of her first and third quarter she is not in the line drawn through the centres of the earth and sun, as she is at the time of new and full moon. This inequality sometimes amounts to 2° 51′.

47. *Nebulæ* are clusters of small stars, which have been chiefly discovered by the telescope. They have received this appellation from their cloudy appearance.

Maculæ are dark spots which are frequently seen upon the disc of the sun.

48. *Faculæ* are certain bright spots frequently seen on the disc of the sun.

49. *Centrifugal Force* is that force by which a revolving body endeavours to recede or fly off from the orbit or path in which it revolves.

50. *Centripetal Force* is that force by which a body is drawn towards the centre of the path or orbit it describes, and prevents it from flying off.

51. *Penumbra*, a faint shadow which borders the dark shade produced by an eclipse.

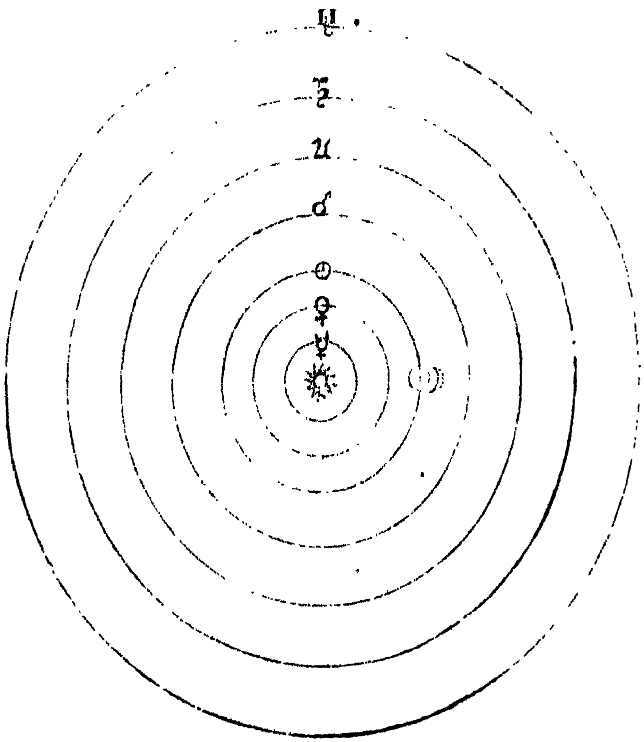
52. *Digit*, the twelfth part of the sun or moon's diameter.

* When any planet appears on the face of the sun, it is said to *transite* his disc.

GENERAL APPEARANCE OF THE HEAVENS TO THE NAKED EYE.

We, tho' from Heav'n remote, to Heav'n will move
With strength of mind, and tread the abyss above
And penetrate, with an interior light,
Those upper depths, which nature hid from sight.
Pleas'd we will be to walk along the sphere
Of shining stars, and travel with the year.
To leave this heavy earth, and scale the height
Of Atlas who supports the heav'nly weight:
To look from upper light, and thence survey
Mistaken mortals wand'ring from the way.

Ovid's Metamorphosis, Book xv.



THE first and most obvious phenomenon of the heavens is the daily rising of the Sun in the east, and his setting in the west; after which the moon and stars appear still keeping the same westerly course, till we lose sight of them altogether. By attending to these

appearances, it must soon be perceived that neither the sun nor the moon rises or sets in the same place. If we begin to observe the sun about the middle of March, he will appear to rise every day sensibly more to the northward than he did the day before, to continue longer above the horizon, and to be more elevated at mid-day. This continues to be the case till the 20th of June, when he begins to move backward in the same manner; and this retrograde motion continues till the 22d of December, when he begins again to move forward, and so on.*

The motion of the Moon through the heavens, and her appearance at different times, are still more remarkable. When the moon first becomes visible to us, she is called *new* moon, and appears in the western part of the heavens, at no great distance from the sun. Every night she increases in size, but removes to a greater distance from the sun, till at last she appears in the *eastern* part of the heavens, just at the time he disappears in the western.

> The western sun withdraws: meanwhile the moon,
> Full orb'd, and breaking thro' the scatter'd clouds,
> Shews her broad visage in the crimson'd east.
>
> THOMSON.

After this, she gradually moves farther to the eastward, and, therefore, rises every night later than the preceding night; till at last she seems to approach the sun as nearly in the east as she did in the west, and rises only a little before him in the morning, as in the first part of her course she set in the west not long after him.

All these appearances take place in the space of a month; after which they begin again in the same order as before. They are not, however, at all times regular; for at some seasons of the year the moon appears to differ little in the time of her rising for several nights together, and at others the difference is very considerable. But this will be more fully stated, and the cause explained, when describing what is called the *harvest moon*.

In contemplating the stars in a clear night, they all appear at the same distance from us, and therefore seem to be situated in the concave surface of a sphere, having the eye for its centre. But when we view them for a considerable time, we find that they change their positions relatively to the objects on the earth, although they still retain their positions relatively to one another, and that they all seem to make progress towards the west, where some of them disappear under the horizon, while others again appear to come above that circle in the east. It will also soon be observed, that many of the stars never go below the horizon at all, but seem to turn round an immoveable point, near which is placed a single star, called the Pole Star.† This point is more or less elevated according to the different parts of the earth from which it is viewed. The inhabitants of Lap-

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* This is only the case in the northern hemisphere, which is the one here alluded to.

† For an explanation of Astronomical terms, see page 8.

land, for example, see it more elevated above their horizon than the inhabitants of Great Britain; they see it more elevated than the inhabitants of Spain and Italy; and they see it still more elevated than the inhabitants of the West India Islands. By continually proceeding southward, this star will seem depressed to the horizon, and at last lost sight of altogether; but another point will appear directly opposite to it, round which the stars in the southern hemisphere will appear to turn. There is, however, no star so near this point as in the northern hemisphere; neither are the stars so numerous in the southern as in the northern half of the heavens.

The general appearance of the heavens is, therefore, that of a vast concave sphere, turning round two fixed points once in twenty-four hours.

> These are Thy glorious works, Parent of Good!
> Almighty! Thine this universal frame,
> Thus wondrous fair! Thyself how wondrous then!
> Unspeakable! who sit'st above the heavens,
> To us invisible, or dimly seen
> In these Thy lowest works; yet these declare
> Thy goodness beyond thought, and power divine!
>
> MILTON.

OF THE BODIES WHICH COMPOSE THE SOLAR SYSTEM.

THE SUN.

> Hail, amiable vision! every eye
> Looks up and loves thee! every tongue proclaims
> 'Tis pleasant to behold thee.
>
> FAWCETT.

> O Sun!
> Soul of surrounding words! in whom best seen
> Shines out thy Maker!
> 'Tis by thy secret, strong, attractive force,
> As with a chain indissoluble bound,
> Thy system rolls entire.
> Informer of the planetary train!
> Without whose quick'ning glance their cumbrous orbs
> Were brute unlovely mass, inert and dead,
> And not, as now, the green abodes of life!
>
> THOMSON.

Of all the celestial bodies, the Sun is certainly the most wonderful. It is the fountain of light which illuminates the world; it is the cause of that heat which maintains the productive power of nature, and makes the earth a fit habitation for man; it is the central body of the planetary system, and is so far superior in lustre to all other celestial bodies, that they disappear in its presence.

> No stars besides their radiance can display
> In Phœbus' presence, the dread lord of day;
> Ev'n Cynthia's self, tho' regent of the night,
> Is quite obscur'd by his emergent light.

The sun is the largest body yet known in the universe; its diameter being 887,693 English miles, its circumference 2,800,000, and its bulk about 1,400,000 times that of the earth. The quantity of matter compared with that of the earth has also been stated by La Place to be 337,422 times that of the earth.

The ancients believed that the sun, and all the other celestial bodies, moved round the earth as their common centre; but since the days of Copernicus, this supposition has been daily losing ground, and has now completely given way to the more rational and well established theory, taught by all the astronomers of the present day; namely, that the sun is the centre of the orbits of all those bodies which compose the solar system.

> Hither as to their fountain other stars
> Repairing, in their golden urns draw light,
> And hence the morning planet gilds her horns.
> By his magnetic beam he gently warms
> The universe, and to each inward part,
> With gentle penetration, though unseen,
> Shoots genial virtue even to the deep.
>
> MILTON.

It has, however, been discovered that the sun has a motion on its axis, which is completed in about 25 days 10 hours, as appears from the maculæ, or spots, which have been discovered on his disc by means of the telescope.

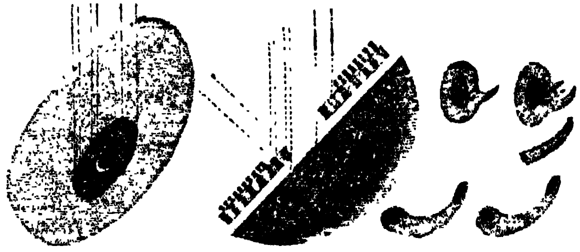
Besides this motion round his axis, the sun has a small motion round the centre of gravity of the system; but if he has any motion in the immensity of space, it must be exceedingly small, as it has never yet been discovered. As for the apparent annual motion of this great luminary round the earth, it can easily be shown, that the real annual motion of the earth round the sun is quite sufficient to cause such an appearance.

NATURE OF THE SUN. ☉

For many ages the sun was believed to be a globe of fire; but the majority of modern astronomers have rejected this opinion, and several of them have published very ingenious hypotheses on this curious subject. One of the most plausible and ingenious theories on this subject is given by Dr. Herschel in the Philosophical Transactions of the Royal Society. He supposes the sun has an atmosphere resembling that of the earth, and that this atmosphere consists of various elastic fluids, some of which exhibit a shining brilliancy, while others are merely transparent. Whenever the luminous fluid is removed, the body of the sun may be seen through those that are transparent. In like manner, an observer placed in the *moon* will see the solid body of the *earth* only in those places where the transparent fluids of our atmosphere will permit him. In others, the opaque vapours will reflect the sun's light, without permitting his solid body to be seen on the surface of our globe.

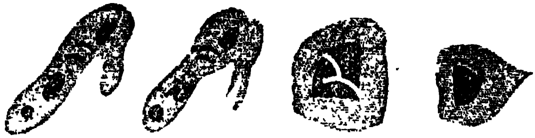
In the same manner the Doctor illustrates the various appearances of spots in the sun, some of which have the following forms: -

Such appearances, he thinks, may be easily and satisfactorily explained, if it be allowed that the real solid body of the sun itself is seen on these occasions, though we seldom see more than its shining atmosphere. He apprehends that there are considerable inequalities in the surface of the sun, and that there may be elevations, not less than 500 or 600 miles in height; that a very high country, or chain of mountains, may oftener become visible by the removal of the obstructing fluid than the lower regions, on account of its not being so deeply covered by it. In the year 1779, the Doctor observed a spot on the sun large enough to be discerned by the naked eye; for it extended more than 50,000 miles. The following are sections of these, with their various formations of *nuclei* and *umbrae*:



He also says, that he observed a fine large spot in 1783, which he followed up to the edge of the sun's limb; that he plainly perceived it to be depressed below the surface of the sun, and that it had very broad shelving sides. This appearance, he says, may be explained by a gentle and gradual removal of the shining fluid which permits us to see the globe of the sun. The Doctor also says, that on the 26th of August, 1792, he examined the sun with several powers, from 90 to 500, and that it evidently appeared that the black spots were the opaque ground, or body of the sun; and that the luminous part was an atmosphere, which, being interrupted, or broken, gave a transient glimpse of the sun himself. He farther adds, that with his seven feet reflector, which was in excellent perfection, he could see the spots, as on former occasions, with the same telescope, much depressed below the surface of the luminous part. On the 8th of September, 1792, he made a small speculum, which he brought to a perfect figure on hones, without polish; this had the effect of stifling a great part of the sun's rays; and on this account the object speculum admitted a greater aperture, which enabled him to see with more comfort and less danger. He then discovered that the surface of the sun was unequal, many parts of it being elevated, and others depressed: but this inequality was in the shining surface only; for he

thinks the real body of the sun can seldom be seen otherwise than in its black spots, which resemble the following:—



As *light* is a transparent fluid, it may not be impossible that the sun's real surface may be now and then perceived; as the shape of the wick of a candle may sometimes be seen through its flame, or the contents of a furnace in the midst of the brightest glare of it. But this the Doctor thinks can only happen where the luminous matter of the sun is not very accumulated.

From these appearances Dr. H. draws the following conclusions: that the sun has a very extensive atmosphere, which consists of various elastic fluids, that are more or less lucid and transparent, and that the lucid one is that which furnishes us with light; that the generation of this lucid fluid on the solar atmosphere is a phenomenon similar to the generation of clouds in our atmosphere, which are produced by the decomposition of its constituent elastic fluids; but with this difference, that the continual and very extensive decompositions of the elastic fluids of the sun are of a *phosphoric* nature, and attended with lucid appearances, by giving out light. To the objection that such decompositions, and consequent emissions of light, would exhaust the sun, Dr. H. replies, that, in the decomposition of phosphoric fluids, every other ingredient except light may return to the body of the sun; and, besides, the exceeding subtilty of light is such, that, in ages of time, its emanation from the sun cannot very sensibly lessen the size of so great a body.

From the atmosphere, the Doctor next proceeds to state that the body of the sun is opaque, of great solidity, and its surface diversified with mountains and valleys; that the sun is nothing else but a large, eminent, lucid *planet*, evidently the first, or, strictly speaking, the *only primary* one of our system, all others being truly *secondary* to it. Its similarity to the other globes of the solar system, with regard to its solidity, its atmosphere, and its diversified surface, the rotation on its axis, and the fall of heavy bodies, lead to the supposition that it is *inhabited*, like the rest of the planets, by beings, whose organs are adapted to the peculiar circumstances of that vast globe. Should it be objected that the heat of the sun renders it unfit for a habitable world, Dr. H. answers, that heat is produced by the sun's rays only when they act on a calorific medium, and that they are the cause of the production of heat by uniting with the matter of fire which is contained in the substances that are heated. The Doctor also suggests other considerations intended to invalidate the objection; but these are too abstruse and extended to be given in this work.

After the Doctor thinks he has shown that the heat of the sun is not so great as to prevent it from being inhabited, he then deduces

from analogy a variety of arguments to confirm the notion of the sun being a habitable body; and then infers, that, if the sun be capable of accommodating inhabitants, the other stars, which are suns, may be appropriated to the same use; and thus, says he, we see at once what an extensive field for animation thus opens to our view.

The late Dr. Wilson, Professor of Astronomy, Glasgow, supposes the spots of the sun are depressions, or excavations, rather than elevations, and that the dark nucleus of each spot is the opaque body of the sun seen through an opening in the luminous atmosphere with which he is surrounded.

To this opinion of Dr. Wilson's, several celebrated astronomers have started objections; among others, M. Lalande, a French astronomer, contends that the spots are appearances arising from dark bodies like rocks, which, by an alternate flux and reflux of the liquid igneous matter of the sun, sometimes raise their heads above the general surface. That part of the opaque rock which at any time thus stands above, gives the appearance of the nucleus, while those parts that lie only a little under the igneous matter appear to us as the *umbra* which surrounds the dark nucleus.

Respecting the nature of fire, and the heating power of the sun's rays, philosophers have been much divided in their opinions; but these opinions are both too numerous and too vague to be noticed in a work like the present. In one particular they all agree, namely, that the sun is either composed of, or surrounded by, some substance that has a very powerful effect in heating or raising the temperature of bodies exposed to the rays which proceed from it.

Many experiments have been made both in this country and on the continent, to determine the intensity of those rays when concentrated in the focus of a lens, or by reflecting mirrors. Among the most powerful of these may be mentioned the mirror constructed by M. Villette, a French artist at Lyons, and publicly exhibited in England. This mirror was 47 inches in diameter, and its focal distance 38 inches. From the experiments of Mr. Harris and Dr. Desaguliers, it appears that it melted a silver sixpence in 7½ seconds; a fossil shell was calcined in 7 seconds; a copper halfpenny melted in 20 seconds; iron ore melted in 24 seconds; a great fish's tooth melted in 32½ seconds; tin melted in 3 seconds; and bone was calcined in 4 seconds.

Sir I. Newton presented a burning glass to the Royal Society, consisting of 7 concave glasses, so placed that the focus of each united in one point. This glass vitrifies brick or tile in 1 second, and melts gold in 30 seconds. So powerful are the sun's rays when condensed, that it is said Archimedes set fire to the Roman fleet, at the siege of Syracuse, by a combination of burning glasses; and Buffon, in the year 1747, constructed a reflecting mirror of 168 plane glasses, moveable on hinges, with which he set wood on fire at the distance of 150 feet, and melted lead at 145 feet.

The time which the light of the sun takes to arrive at the earth is *eight minutes* and *thirteen seconds;* but this will be more fully treated of in another part of this work.

OF THE PLANETS.

The Sun revolving on his axis turns,
And with creative fire intensely burns;
First Mercury completes his transient year,
Glowing, refulgent, with reflected glare;
Bright Venus occupies a wider way,
The early harbinger of night and day;
More distant still our *globe terraqueous* turns,
Nor chills intense, nor fiercely heated burns;
Around she rolls the *lunar orb* of light,
Trailing her silver glories through the night.
Beyond our globe the sanguine Mars displays
A strong reflection of primeval rays;
Next belted Jupiter far distant gleams,
Scarcely enlightened with the solar beams;
With four unfix'd receptacles of light,
He towers majestic thro' the spacious height:
But farther yet the tardy Saturn lags,
And six attendant luminaries drags;
Investing with a double ring his pace,
He circles thro' immensity of space.
CHATTERTON.

Beside the Earth and Moon, ten of the stars have motions *eastward* peculiar to themselves. These are called Planets,* and are distinguished by particular names; which, taken in the order of their proximity to the sun, or of the celerity of their motions round that body, are, Mercury, Venus, Mars, Juno, Vesta, Ceres, Pallas, Jupiter, Saturn, and Uranus,† or Herschel. The first two of these perform their revolution round the sun in less than a year; and as their orbits are included in that of the earth, they are called *inferior* planets.

The rest require a longer period than a year to complete their revolutions round the sun; and as their orbits include that of the earth's, they are called *superior* planets.

Five of the planets; *viz.* Mercury, Venus, Mars, Jupiter, and Saturn, are very conspicuous, and have been known from the earliest ages. The other five are visible only through the telescope, and have been very lately discovered: Uranus, by Dr. Herschel, in 1781; Ceres, by Piazzi, in 1801; Pallas, by Olbers, in 1802; Juno, by Harding, in 1803; Vesta, by Olbers, in 1807.

The planets have also particular characters, by which they are distinguished; these, in the order in which they have been enumerated, are ☿ ♀ ♂ ⚵ ⚶ ⚳ ⚴ ♃ ♄ ♅.

The planets distinguished by these characters are termed *primary* planets, because they perform revolutions round the sun in their respective periodic times; but besides these there are a number of other small planets, that circulate round several of the primary ones, and on that account are called secondary planets, or satellites.

* From a Greek word signifying to wander, because these bodies are continually changing their places.

† Those planets that are nearest the sun move quickest in their orbits.

The *moon* is therefore considered as a secondary, or satellite, because it performs its revolutions round the *earth*. The number of secondary planets at present known is 18.

Of these, one circulates round the earth; four round Jupiter; seven round Saturn; and six round Uranus.

With what an awful world-revolving power,
Here first the unwieldy planets launched along
The illimitable void! There to remain
Amid the flux of many thousand years,
That oft have swept the toiling race of men
And all their laboured monuments away.
Firm, unremitting, matchless in their course,
To the kind-tempered change of night and day
And of the seasons ever stealing round
Minutely faithful: such the All-perfect hand
That poised, impels, and rules the whole.

OF MERCURY. ☿

Mercurius nearest to the central sun
Does in an oval orbit circling run;
But rarely is the object of our sight,
In solar glory sunk, and more prevailing light.

BLACKMORE.

Mercury is the nearest planet to the sun, and performs his revolution round that luminary in the shortest period of all the planets. The time he takes to perform this revolution is 87^d 23^h 14′ 32·7″,* which is the length of his year. The length of his day, or the time he takes to perform a revolution round his axis, is not known; for, by reason of his proximity to the sun, few observations can be made upon him. The German astronomer, Shroeter, is however of opinion, from some observations that he made on this planet, that the length of his day is 24 hours 5 minutes; he also conceives that there is a mountain on the surface of Mercury not less than 10¾ miles in height, but this has not yet been correctly ascertained. He is so near the sun, that he can seldom be seen; and when he does make his appearance, his motion is so rapid towards the sun that he can only be discerned for a very short time. When he can be seen, it is a little before the sun rises in the morning, and a little after he is set in the evening. His distance from the sun is 36,668,373 English miles, and his diameter is 3,241 miles, which makes him about $\frac{1}{17}$th part of the size of the earth. The rate at which he moves in his orbit is not known. His situation with regard to the sun is such, that water would be kept continually boiling on that part of his surface which is opposite to the sun. The light and heat he receives

* The time which any planet takes to perform its revolution round the sun, is called the length of its year; and the time which it takes to revolve round its axis, the length of its day.

from the sun are seven times greater than the earth, and the sun appears seven times as large to him as to the earth.

This planet appears to us with all the various phases of the moon, when viewed at different times with a good telescope; but he never appears quite full, because his enlightened side is never turned directly towards the earth, except when he is so near the sun as to be lost to our sight in his beams. His enlightened side being thus always turned towards the sun, proves that he shines not by any light of his own; for if he did, he would always appear round, and fully enlightened. It is also plain he moves in an orbit within that of the earth's, because he is never seen opposite to the sun, nor above 56 times the sun's breadth from him, his greatest Elongation being about 28°.

Mercury is the smallest of all the primary planets, and moves the quickest in his orbit. Hence it was that the Greeks gave this planet its name after the nimble messenger of the gods, and represented it by the figure of a youth with wings at his head and feet; whence is derived ☿, the character by which it is commonly represented.

The inclination of the orbit of Mercury to the plane of the ecliptic is the greatest of all the planets, being 7°; and it is also far more eccentric than that of any of the other planets, being not less than ¼th of his mean distance from the sun. The best observations which can be made on this planet are, when it is seen on the sun's disc, called its *transit;* for in its inferior conjunction, or when it is between the earth and the sun, it sometimes appears to cross the sun like a little dark spot, eclipsing a small part of the sun's body, which is only visible with a telescope. The first observation of this kind was made by Gassendi, a French astronomer, in November 1631. Seven transits of this planet have been observed since that time. The next one that will take place will be in May 1832, but it will not be visible in Great Britain.

It has been very justly observed by the celebrated Huygens, that the astronomy of those who live in Mercury may be easily understood by the Copernican system; and that the planets, Venus and the earth, at the time of their opposition, must appear very bright and large to the inhabitants of Mercury. For if Venus shines so splendidly to us when she is new and horned, she must appear six or seven times larger to the inhabitants of Mercury when she is in opposition to the sun, and afford them so strong a light, that they can have no reason to complain of the want of a moon.

Whether they have any difference of seasons is quite uncertain, because it is not known whether the axis of this planet has any inclination to its orbit, or what is the time of its diurnal revolution. But as Mars, the Earth, Jupiter, and Saturn, certainly have such successions, there can be no doubt that days and nights, and a vicissitude of seasons, are experienced in Mercury in some degree, as well as in the other planets.

OF VENUS. ♀

Next Venus, to the westward of the Sun,
Full orbed her face, a golden plain of light
Circles her larger round. Fair morning star,
That leads on dawning day to yonder world,
The seat of man.

———————— Fair Venus shines
Even in the eye of day; with sweetest beam
Propitious shines, and shakes a trembling flood
Of softened radiance from her dewy locks.

BARBAULD.

Venus is the next planet in order, after Mercury, and the most brilliant of all the planets, Jupiter not excepted. She is represented by the character ♀, which is supposed to be a rude representation of a female figure, with a trailing or flowing robe. It is the only planet mentioned in the sacred writings, or by the most ancient poets, such as Hesiod and Homer. Venus never recedes far from the sun, her greatest Elongation being about 47°; which proves that her orbit includes that of Mercury, but is included by that of the earth. When Venus is to the *west* of the sun, she is to be seen before the sun rises, and is then called the *morning* star; but when she is to the *east* of the sun, she is to be seen after he is set, and is then called the *evening* star. When in the former of these situations, she was called by the Greeks Phosphorus, and in the latter Hesperus. The evening and morning stars were at first supposed to be different; and it is said that Pythagoras was the first person who discovered that they were the same.

Now came still evening on; and twilight grey
Had in her sober livery all things clad;
Silence was pleas'd: now glow'd the firmament
With livid sapphires: Hesperus, that led
The starry host, rode *brightest;* till the moon
Rising in clouded majesty, at length,
Apparent queen, unveil'd her peerless light,
And o'er the dark her silver mantle threw.

MILTON.

Venus is computed to be 68,518,044 miles distant from the sun; she moves at the rate of 76,000 miles per hour; and completes her siderial revolution round the sun in 224 days, 16 hours, 49 minutes, 10 seconds.

The time she takes to revolve round her axis, or the length of her day, is by some astronomers stated at 23h 21′, and by others at 24d 8h. Venus is much about the size of our earth, her diameter being 7687 English miles. When examined by a good telescope, she exhibits the same phases as Mercury and the moon; and her surface is occasionally variegated by darkish spots. These spots were employed by Cassini and Bianchini in determining the revolution of Venus about her axis.

When Venus is an evening star, and at her greatest distance from the sun, or at what is termed her *greatest eastern elongation*, she appears, when viewed with a telescope, to have a semicircular disc,

like the moon in the last quarter, with its convexity turned to the west. From that time, during her approach to the sun, her splendour increases for a while, though the quantity of the illuminated disc diminishes like the moon in the wane; but her diameter, when measured by the distance of the horns, is found to be increased.

At the time of her greatest elongation, Venus appears to be stationary, with respect to the sun, for some time. After this, her motion eastward becomes slower than the sun's, and then she approaches nearer to the sun, as just remarked. At a certain point she becomes stationary with respect to the fixed stars, and then her motion becomes retrograde, or appears to be directed westward, with respect to the fixed stars. At last she approaches the sun, so as to be lost in his light; but after some time, she is to be seen to the west of the sun, and appears in the morning before he rises. As she proceeds to the westward, her illuminated disc is seen as a crescent continually increasing, at the same time that her diameter is diminishing. When she has got 45° to the west of the sun, her disc is a semicircle; and as she again approaches the sun, it increases till she is lost in the sun's rays; her orb being almost a circle, but its diameter not more than one-sixth of what it was at the former conjunction. The conjunction, which takes place after the western elongation of Venus, is called the *superior* conjunction, as she is then farthest from the earth; and that which follows the eastern elongation is called the inferior *conjunction*, as she is then nearest the earth. At the former of these periods, Venus is the breadth of her orbit farther from the earth than at the latter; for at the time of the superior conjunction, she is on the opposite side of the sun to what the earth is; but at the time of the inferior conjunction, Venus and the earth are both on the same side of the sun. This planet appears to keep on the same side of the sun for 290 days together, although this is a longer period than she takes to perform a complete revolution round that luminary. This may appear strange to those who are but little acquainted with astronomy; but when it is considered that the earth is all the while going round the sun the same way, though not so quick as Venus, the difficulty vanishes; because she must continue to appear on the same side with the earth, till the excess of her daily motion above that of the earth's amounts to 179°, or nearly to half a circle; which, at the rate of 37 minutes per day, will be in about 290 days, as stated above.

After the superior conjunction, the orb of Venus increases in magnitude as she approaches her greater eastern elongation, but the enlightened part diminishes, just reversing the order of what has already been stated to take place from the inferior conjunction to her greatest western elongation; the period which includes all those changes, or the time which elapses between any conjunction, and the next of the same sort, is 584 days. This is called the Synodical Revolution of Venus, during 42 days of which she is *retrograde*, with respect to the fixed stars. To us Venus appears brightest when her elongation is about 40°, which happens about 70 days both before and after her *inferior conjunction*.

The different phases, or appearances of Venus, described above, were first discovered by the astronomer Galileo in 1611, which fulfilled the predictions of Copernicus; who foretold, before the discovery of the telescope, that the phases of the *inferior* planets would be one day discovered to be similar to those of the moon. The accomplishment of this prediction affords some of the strongest and most convincing proofs of the truth of the Copernican system of the world that can be obtained.

It was long doubted whether Venus be surrounded by an atmosphere or not; but this question has been completely settled by the very nice and accurate observations of the German astronomer Shroeter, who has ascertained the existence of a pale faint light extending along the line of the dark hemisphere of this planet, which he supposes to be a kind of twilight occasioned by the sun illuminating its atmosphere. From this circumstance, Shroeter has been enabled to determine the density of this atmosphere, and that it extends to a very great height, which must necessarily prevent the sun from overpowering the inhabitants with his heat and splendour, which is more than double what it is on the earth.

Dr. Herschel, after a long series of observations on this planet, says, that it is highly probable that its surface is diversified by hills and valleys, although he has never been able to see much of them, owing, perhaps, to the great density of its atmosphere; and, he adds, that no eye which is not considerably better than his, or assisted by much better instruments, will ever get a sight of them.

Some astronomers have imagined that they perceived a satellite near Venus; but this has since been proved to be an illusion: for, in her transit over the sun's disc, she appeared unaccompanied by any satellite. Mr. Ferguson, however, thinks that Venus may have a satellite revolving round her, though it has not yet been discovered; and adds, "that this will not appear very surprising, if we consider how inconveniently we are placed for seeing it."

Venus, as well as Mercury, is sometimes seen like a dark spot on passing over the body of the sun. This phenomenon, as already stated, is called a transit; but such an appearance can only happen at the time of an inferior conjunction, and when that conjunction takes place at the time Venus is in that part of her orbit which crosses the earth's orbit.* Transits of Venus but seldom happen. The first that ever was observed was seen by our countryman, Mr. Horrox, in 1639; two others have taken place since: viz. in 1761, and the other in 1769; but there will not be another till 1874.

When a transit of Venus is observed, it not only proves that she is an *opaque* body, and that her orbit is included by the earth's, but it is of admirable use in determining what is called the sun's parallax, which is of so much use in practical astronomy. See page 9th of this work, Art. 25.

* The two points where the orbit of a planet crosses the ecliptic, or earth's orbit, is called its nodes.

OF THE EARTH. ⊕

More distant still our Earth comes rolling on,
And forms a wider circle round the sun;
With her the moon, companion ever dear;
Her course attending through the shining year.

BAKER.

The earth performs its revolution round the Sun in an orbit between that of Venus and Mars, at the distance of 95,173,000, in 365 days, 5 hours, 48 minutes, 49 seconds, which is called the solar or tropical year. In performing its annual circuit, the Earth travels at the rate of 68,000 miles every hour, which is 140 times faster than that of a cannon ball. The diameter of the Earth is 7,912 English miles, and its circumference 24,855·42 miles.*

The Earth is usually represented by the character ⊕, in works which treat of Astronomy.

In the early ages of the world, many fanciful and absurd notions respecting the figure of the Earth prevailed; some of which were adopted because they appeared to agree with the slight and inaccurate observations of the vulgar, whilst others represented this matter in the way which best accorded with their preconceived opinions in philosophy or religion. The most general opinion was, that the Earth was a great circular plane, extending on all sides to an infinite distance; that the firmament above, in which all the heavenly bodies seem to move daily from east to west, was at no great distance from the Earth; and that all the celestial bodies were created solely for its use and ornament.† *Cosmas Indopleustes* supposed that it was an immense plane, whose length was much greater than its breadth, and surrounded by an unpassable ocean.—Towards the north he placed a huge mountain, round which the sun and stars performed their diurnal revolutions; and from the conical shape which he ascribed to it, with the oblique motion of the sun, he accounted for the inequality of the days and the variety of the seasons. The vault of heaven he conceived rested upon the earth, which extended beyond the ocean, and supported by two vast columns. Beneath the arch, angels conducted the stars in their various motions; above it were the celestial waters, and over all he placed the supreme heavens.

Concerning the figure and infinitude of the Earth no accurate information can be derived from the ancients. But this is not to be wondered at when we consider that they were not only unacquainted with the laws of motion, and the use of all optical and mathematical instruments; but they were unacquainted with the very existence of extensive islands and countries at no great distance from their own.

* This is what the French mathematicians have lately deduced from a measurement of above 12° of the meridian.

† Heraclitus imagined the earth to have the shape of a canoe; Anaximander supposed it to be cylindrical; and Aristotle, the great oracle of antiquity, gave it the form of a *timbrel*.

A very little reflection, however, and a very little travelling either by sea or land, must soon convince any one that the earth is of a spherical form. For let a person occupy any station in a level country, and mark carefully the objects within the range of his horizon, let him then advance in any direction, and as he moves the objects behind him gradually disappear and new objects in front come in view. Before he has travelled twenty miles in the same direction, he will find that every object which was at first visible to him is lost to his view, and that he is now in the centre of a new horizon. As a similar change takes place at every part of the globe where the experiment is tried, it follows that the earth is a spherical body. The same inference may be deduced from observing the appearance of a ship at a distance at sea, or from observing the gradual rising of the coast as a ship approaches the shore. In the former case the top of the mast is first seen, and as the vessel approaches the land the whole of her gradually becomes visible: in the latter, the hills, or the higher parts of the buildings, are first discovered, but by degrees every par of the buildings, and even the beach itself is seen.

These are appearances which can only be reconciled with the spherical figure of the earth. The same conclusion may be drawn from observing the altitude of the Pole star after travelling north or south a considerable number of miles. In travelling northward its altitude will be increased; but in travelling south it will be diminished.

The globular figure of the earth is also inferred from the operation of levelling, in which it is found necessary to make an allowance for the difference between the *true* and *apparent* level—and the allowance which is made, and found to answer, is on the principle that the earth is spherical.

Another proof of the earth being of a spherical form is obtained from its shadow in an eclipse of the moon. For when the shadow of the earth falls on the moon she is eclipsed, and the shadow always appears circular upon the face of the moon, when she is not totally eclipsed, although the earth is constantly turning on its axis. Hence it follows that the body that projects it must be *spherical.*

But the most convincing proof of the spherical figure of the earth, is that many navigators have sailed round it; not on an exact circle it is true, because the winding of the shores would not admit of it, but by going in and out as the shores happened to lie, and still keeping the same course, they have at last arrived at the port from which they departed. Among those who have succeeded in this daring enterprise, may be mentioned Magellan, a Portuguese, in the year 1519, who completed the voyage in 1124 days; Francis Drake performed the same in 1056 days; Sir Thomas Cavendish in 777 days; Van Schoulen in 749 days; and many others have since performed the same navigation, particularly Anson, Baugainville, and Cook.

Some of these navigators sailed eastward, some westward, till they again arrived in Europe; and in the course of their voyage observed

that all the phenomena, both of the heavens and the earth, confirmed the doctrine of the spherical figure of the earth.

The unevenness or irregularity of the earth's surface, such as mountains and valleys, afford no objection to its being considered as a globular body; for the loftiest mountains bear no greater proportion to the vast magnitude of the earth, than grains of sand to the size of an artificial globe of twelve inches in diameter. This is the reason that no deviation from the spherical figure of its shadow is perceptible in an eclipse of the moon.

Although every one of the observations which have just been made respecting the figure of the earth, affords sufficient evidence that the surface of the earth is curved, yet none of them, except, perhaps, the form of the shadow on the disc of the moon in a lunar eclipse, entitles us to infer that the figure of the earth is that of a globe, or perfect sphere. It was natural, however, for those who first discovered that the earth had a round shape, to suppose that it was truly spherical. This, however, is now known not to be the case. Its true figure being that of an oblate spheroid, or sphere, flattened a little at the poles, and raised about the equator, so that the polar diameter is less than the equatorial. What first led to this discovery was the observations of some French and English philosophers in the East Indies and other parts, who found that pendulums required longer time to perform their vibrations the nearer they were to the equator. For Mr. Richer in a voyage to Cayenne, near the equator, found that it was absolutely necessary to shorten the pendulum of his clock about one-eleventh part of a Paris inch, in order to make it vibrate in the same time as it did in the latitude of Paris.

From this it appeared that the force of gravity was less at places near the equator than at Paris; and consequently that those parts are at a greater distance from the earth's centre. This circumstance put Newton and Huygens upon attempting to discover the cause, which tney attributed to the revolution of the earth on its axis. If the earth were in a fluid state, its rotation on its axis would necessarily make it assume such a figure, because the *centrifugal* force being greatest towards the equator, the fluid would there rise and swell most; and that its figure really should be so now, seems necessary to keep the sea in the equatorial regions from overflowing the land about those parts.

Newton in his Principia demonstrates, that by the operation of the power called gravity, the figure of the earth must be that of an *oblate spheroid*, if all parts of the earth be of a uniform density throughout, and that the proportion of the polar to the equatorial diameter would be 229 to 230 nearly.

As all conclusions, however, deduced from the length of pendulums at different places of the earth's surface, proceed upon the supposition that the earth is a homogeneous body, which is very improbable, the true figure of the earth can scarcely be expected to be discovered by the pendulum; and at any rate it can be of no use in determining the magnitude of the earth. A solution of this important problem has, however, been attempted at various periods, by other

means, and has at last been accomplished in a most accurate and satisfactory manner, by the actual measurement of a very large arc of a meridian circle on the earth's surface. The earliest attempt of this kind of which we have any account, is that of Eratosthenes of Alexandria, in Egypt. By measuring the sun's distance from the zenith of Alexandria, on the solstitial day, and by knowing, as he thought he did, that the sun was in the zenith of Syené, on the same day, he found the distance in the heavens between the parallels of these places to be 7° 12′, or a fiftieth part of the circumference of a great circle. Supposing, then, that Alexandria and Syené were on the same meridian, nothing more was required than to find the distance between them, which multiplied by 50, would give the circumference of the globe. But it does not appear that Eratosthenes took any trouble either to ascertain the bearing or the distance of the two places; for Syené is considerably east of Alexandria, and it appears that the distance was not measured till long afterwards, when it was done by the command of the Emperor Nero, A similar attempt was made by Passedonius, who lived in the time of Pompey; but it is impossible for us to judge how far these results correspond with the more accurate measurements of the moderns, as we are unacquainted with the *stadium*, the measure in which the results were expressed.

The first arc of the meridian measured in modern times with any degree of accuracy, was by Snellius, a Dutch mathematician. The arc was between Bergen-op-zoom and Alkmaar, and the length of the degree that resulted was 55,021 toises; but upon repeating the operations afterwards with greater accuracy, the degree came out 57,033 toises, which is not far from the truth.

Our countryman, Mr. Norwood, measured the distance between London and York, from whence he deduced the length of a degree to be 57,800 toises, which has been found to be a near approximation, considering the method he took to determine it. For he says, "Sometimes I measured, sometimes I *paced*, and I believe I am within a *scantling* of the truth."

Picard was the first person who employed the trigonometrical method with any degree of accuracy; but since his time very large arcs of the meridian have been measured in various parts of the world, particularly in Lapland, Peru, India, France, and England. The arc which has been measured in France extends from Dunkirk in lat. 51° 2′ 9″ N. to Formentera, the southernmost of the Balearic isles in lat. 38° 38′ 56″ N. comprising an arc of 12° 23′ 13″. But this has lately been extended to the Shetland islands. The whole amplitude of the arc is therefore above 22°.

From comparing the lengths of the degrees of the meridian which have thus been measured at different parts of the earth with each other, it is found that they gradually increase in length from the equator to the poles; which proves beyond the possibility of doubt, that the true figure of the earth is that of an oblate spheroid, its polar diameter being to the equatorial as 311 to 312. And by taking the mean length of a degree, or that measured in France at latitude 45°,

and multiplying it by 360, the degrees in the circle, the circumference of the earth in the direction of the meridian is found to be 24,855·84 English miles. The circumference of the equator is 24,896·16 miles, which is about 40 miles greater than the preceding. The mean diameter of the earth is therefore 7910 nearly, and the length of one degree 69$\frac{1}{10}$ English miles.

OF MARS. ♂

In larger circuit rolls the orb of Mars,
Guiltless of stern debate, and wasteful wars,
As some have erring taught: he journies on,
Impell'd and nourish'd by the attractive sun;
Like us, his seasons and his days he owes
To the vast bounty which from Phœbus flows.

BROWN.

Mars is the next planet, after the earth, in the order of distance from the sun; and as his orbit includes that of the earth, he is called the first of the *superior* planets. He is usually represented by the character ♂, which is said to be rudely formed from a man holding a spear protruded, representing the god of war, which is the title of Mars in the heathen mythology.

He may easily be distinguished from any other planet, or star, by the red colour of his light.

Mars is the smallest of all the ancient planets, except Mercury, his diameter being about 4200 miles. The time he takes to perform his sedereal revolution round the sun is 686 days, 23 hours, 30 minutes, 36 seconds, which is performed at the distance of about 145 millions of miles, at the rate of 55,000 miles per hour. The time he takes to revolve on his axis is 24 h 39′ of our time. The quantity of light and heat which Mars receives from the sun is only about half what the earth receives from him; and the sun only appears half as large to Mars as to the earth. If any satellite revolves round Mars it must be very small, as it has not yet been discovered, notwithstanding the great number of observations which have been made on this planet with the most powerful telescopes.

To Mars, the earth and moon appear like two moons, a larger and a smaller, changing places with each other, and appearing sometimes horned, sometimes half and three quarters enlightened, but never full; and never above a quarter of a degree distant from one another, although they are 240,000 miles asunder.

The red colour of this planet is ascribed to the density of its atmosphere. For the atmosphere which surrounds Mars is not only of great density, but of great height, that is, extends a great way from his surface, as appears from the occultations to which the fixed stars are subject on approaching his disc.

Dr. Smith, in his Optics, mentions an observation made by Cassini, on a star in the constellation Aquarius, at the distance of six

minutes from the disc of Mars, that became so faint before its occultation that it could not be seen by the naked eye, nor even with a three-feet telescope.

From a series of observations, Dr. Herschel found that the poles of Mars were distinguished by very remarkable luminous spots. These he employed* to determine the situation of the axis of the planet, and its inclination to the ecliptic, &c. Their magnitude and splendour were sometimes very considerable, but subject to very great variations. The Dr. supposes that they are produced by the reflection of the sun's light from the snow near the poles; and that the variations in their size and brightness is owing to the melting of the polar ice.

Dr. H. has also determined that Mars is of a spheroidical form, somewhat similar to that of the earth, having its equatorial diameter to the polar as 103 to 98. When we reflect on the general appearance of this planet, we soon find that opportunities for making observations on its real form cannot be very frequent: for when it is near enough to be viewed to advantage, we generally see it gibbous, or more than half illuminated, and its oppositions are so seldom, and of so short duration, that in the space of two years there is not above three or four weeks for making such observations. It is therefore not at all surprising that the spheroidical form of this planet should not have been discovered before the time of Dr. Herschel.

As the orbit of Mars includes that of the earth, at the time of his opposition to the sun he is nearly five times nearer the earth than at the time of his conjunction; he therefore appears nearly five times greater at the former of those periods than at the latter. And by observing his oppositions in different parts of the heavens, or when he is in different parts of his orbit, his apparent diameter is nearly the same; hence it is inferred that the sun is nearly in the centre of the orbit of Mars, or that it does not deviate much from a circle;* the same appearance is observed when Jupiter and Saturn are in a similar situation; it is therefore concluded that the orbits of these planets are also nearly circular.

Mars appears with his disc perfectly round both at the time of opposition and conjunction. In the intermediate positions, he is found to want something of perfect rotundity, on the side turned farthest from the sun. This not only proves that Mars receives his light from the sun, but that his orbit includes that of the earth.

When Mars first emerges from the sun's rays, a few days after the conjunction, he rises some minutes before the sun, and his motion is found to be progressive, that is, he changes his place daily a little towards the east. But the earth's motion in the same direction is nearly double that of Mars, which has the effect of making that planet appear to recede from the sun towards the west, though its real motion, with respect to the fixed stars, is toward the east. This

* Although the orbit of Mars does not deviate greatly from a circle, yet it is the most eccentric of all the ancient planets, except that of Mercury.

continues for nearly a year, when his angular distance from the sun is about 137°, he then appears to be stationary for a few days. After this, his motion becomes retrograde, or toward the west, and continues so till he is 180° distant from the sun, or in opposition, so as to be on the meridian at midnight. His retrograde motion is then swiftest; it afterwards becomes gradually slower, and ceases altogether when the planet has again come to be about 137° distant from the sun on the other side. The motion then becomes progressive again, and continues so till the conjunction, and beyond it, in the manner just described. The period in which all those changes take place, or the interval between one conjunction, or opposition to the next, is 780 days, which is the length of a synodical revolution of this planet.

The irregularities of Mars, in his orbit, being the most considerable of all the primary planets, Kepler fixed upon it as the first object of his investigations respecting the nature of the planetary orbits; and after extraordinary labour, he at last discovered that the orbit of this planet was elliptical; that the sun is placed in one of the foci; and that there is no point round which the angular motion is uniform.

In the pursuit of this inquiry he found the same thing of the earth's orbit; hence, by analogy, it was reasonable to think, that all the planetary orbits are elliptical, having the sun in their common focus.*

OF CERES.

This and the three following planets have all been discovered since the beginning of the present century, and within the space of six years.

Ceres was discovered on the 1st of January, 1801, by Mr. Piazzi at Palermo in Sicily.

Its diameter, according to Dr. Herschel, is only 163 miles. But Shroeter makes it 1624 miles. This great difference, says Shroeter, arises from Dr. H. observing with his projection-micrometer at too great a distance from his eye, and measuring only the middle clear part of the nucleus.

Ceres moves in an orbit between Mars and Jupiter; and its mean distance from the sun is about 263,000,000 miles. The time it takes to perform its sidereal revolution round the sun in 1681 days, 12 hours, 56 minutes. The excentricity of its orbit is a little greater than that of Mercury; and its inclination to the ecliptic exceeds that of

* Logarithms not having been discovered at that time, arithmetical calculations, when pushed to great accuracy, required both great patience and great labour. In the calculation of every opposition of Mars, the work filled ten folio pages, and Kepter composed together seven oppositions of this planet, repeating each calculation ten times; so that the work for each opposition filled 100 such pages, and the whole calculation for the seven oppositions produced a large folio volume.

all the old planets very considerably. Ceres is not visible to the naked eye; but when observed by a telescope, appears of a ruddy colour, and about the size of a star of the eighth magnitude. It also seems to be surrounded by an extensive and dense atmosphere; but when examined by a telescope, which magnifies it above two hundred times, its disc may be very distinctly perceived.

OF PALLAS. ⚴

The planet Pallas was discovered at Bremen, in Lower Saxony, on the 28th March, 1802, by Dr. Olbers. It moves in an orbit between that of Mars and Jupiter, and its mean distance from the sun is nearly the same as Ceres; but the inclination of its orbit to the ecliptic is much greater, being not less than $34\frac{1}{2}^{\circ}$. The time it takes to perform its sidereal revolution round the sun, is about five hours more than Ceres; and it appears also to be about the same magnitude. It is less ruddy than Ceres; but is surrounded by an atmosphere similar to what surrounds that planet. It likewise undergoes similar changes, but its light exhibits greater variations.

OF JUNO. ⚵

The planet Juno was discovered by Mr. Harding at the observatory of Lilianthal, near Bremen, on the evening of the 1st of September, 1801, while he was making a catalogue of all the stars which were near the orbits of Ceres and Pallas. Its diameter, according to Shroeter, is 1425 miles; and its mean distance from the sun is about 253,000,000 miles. The time it takes to perform its sidereal revolution round the sun is nearly 1590 days. The orbit in which it performs its revolution round the sun is situated between that of Mars and Jupiter, and is so eliptical that its greatest distance from the sun is nearly double its least distance. This great excentricity has a remarkable effect on the motion of the planet in its orbit: for it moves through that half of its orbit which is nearest the sun nearly in half the time that it moves through the other. The inclination of the orbit to the ecliptic is about 13°.

Juno is of a reddish colour, and free from that whitish light which surrounds Pallas

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OF VESTA. ⚶

This planet was discovered by Dr. Olbers, of Bremen, on the 29th March, 1807. Its diameter is stated at 238 miles; but Shroeter makes it much greater. The orbit of Pallas is situated between the orbits of Mars and Jupiter; but nearer the former than any of the other new planets. The time it takes to perform its sidereal revolu-

tion round the sun is 1335 days, 4 hours, 54 minutes. Its mean distance from the sun is about 225,000,000 miles.

In a clear evening this planet may be seen by the naked eye, like a star of the sixth magnitude, of a dusky colour, similar in appearance to Uranus,—its light being more intense, pure, and white, than any of the other three new planets.

It appears rather extraordinary that the orbits of the four new planets, just described, should all be nearly at the same distance from the sun, and in a part of the heavens, where it was conjectured some planet might perform its revolution round the sun, although no astronomer had ever been so fortunate as to discover it. What led to this supposition was the great distance between the orbits of Mars and Jupiter, a thing so unlike the regular order in which the orbits of the planets between the sun and Mars were disposed. Accordingly, upon the discovery of Ceres, the harmony and regularity of the system seemed to be established; but the subsequent discovery of Pallas and Juno, seemed again to overturn these speculations. This new difficulty suggested to Dr. Olbers, what may perhaps be considered a very romantic idea, namely, that the three recently discovered planets might be fragments of a planet, which had been burst asunder by some internal convulsion. This opinion seemed to receive considerable support from a comparison of their magnitudes with that of all the other planets: from the circumstance of their orbits being nearly at equal distances from the sun; and from the very singular fact, that all their orbits cross one another in two opposite points in the heavens.

The support which this hypothesis derived from the last of these circumstances is peculiarly strong and conclusive; for it can be demonstrated, that if a planet, in motion, be rent asunder by any internal force, however different the inclinations of the orbits of the fragments may be, they must all meet again in two opposite points. Prosecuting this idea, Dr. Olbers every year examined the small stars that were near these points in the heavens, and was so fortunate as to discover a fourth fragment, or the last discovered planet Vesta. Dr. Brewster, of Edinburgh, has suggested another view of the subject, which seems to give additional support to the theory of Olbers. If a planet, says Dr. B., be rent asunder by any explosive force, the form of the orbits assumed by the fragments, and their inclination to the ecliptic, or to the orbit of the original planet, will depend upon the size of the fragments, or the weight of their respective masses: the larger masses will deviate least from the original path, while the smaller fragments being thrown off with greater velocity, will revolve in orbits more eccentric, and more inclined to the ecliptic. Now this is precisely what happens. Ceres and Vesta are found to be the largest, and their orbits have nearly the same inclination to the ecliptic as some of the old planets; while the orbits of the smaller ones, Juno and Pallas, are inclined to the ecliptic, 21° and 34° respectively.

As to these four bodies, so very unlike the other primary planets, Dr. Herschel has given the name of Asteroids. La Lande and some

others have named each of them after the person who discovered it; but this produces some degree of confusion, because Dr. Olbers discovered both Pallas and Vesta.

OF JUPITER. ♃

Beyond the sphere of Mars, in distant skies,
Revolves the mighty magnitude of Jove,
With kingly state, the rival of the Sun.
About him round, four planetary moons,
On earth, with wonder, all night long beheld,
Moon above moon, his fair attendants dance.

Jupiter performs his revolution round the sun in an orbit, which includes all the planets yet described. His mean distance from the sun is about 490 millions of miles; and the time he takes to complete a sidereal revolution round that luminary is 4332 days, 14 hours, 27 minutes. The motion on his axis is extremely rapid, being performed in the short space of 9 hours, 56 minutes; but his hourly motion in his orbit is only 25,000 miles.

Jupiter is the largest of all the planets, his diameter being 89,170 English miles.

Next Jove, prodigious planet of the skies!
His orb presents of huge amazing size.

BROWN.

Jupiter is also the brightest of all the planets, except Venus, which, on some occasions, exceeds him in splendour. The character by which he is represented is ♃.

Jupiter is surrounded by faint substances, called zones, or belts, which lie parallel to each other on his surface. They are, however, subject to considerable variation both in breadth and number and are on some occasions more conspicuous than at others. They are not only parallel to each other, but, in general, parallel to the equator of Jupiter. Bright and dark spots are also frequently to be seen in the belts; and when a belt vanishes, these spots vanish with it. The broken ends of some belts have often been observed to revolve in the same time with the spots; only those near the equator of the planet more quickly than those nearer the poles. This is, perhaps, on account of the greater heat of the sun near the equator than the poles; the equator being parallel to the belts and course of the spots. On some occasions the spots have been observed to change their forms gradually, and sometimes with very unequal velocities.

Astronomers are very different in their opinions respecting the cause of these appearances. Some consider them as the effect of changes in the atmosphere that surround Jupiter; while others regard them as indications of great physical revolutions on the surface of that planet. The first of these hypotheses appears to explain the variations in the *form* and *magnitude* of the belts; but it by no means accounts for their *parallelism*, nor for the permanence of some of the

spots. The spot first observed by the astronomer Cassini, in 1665, which has both disappeared and reappeared in the same form within the space of 50 years, seems evidently to be connected with the surface of the planet. The form of the belts, says Dr. Brewster, may be accounted for, by supposing that the atmosphere of Jupiter reflects more light than the body of the planet, and that the clouds which float in it, being thrown into parallel strata by the rapidity of his diurnal motion, form regular interstices, through which are seen the opaque body of Jupiter, or any of the permanent spots which may happen to come within the range of the opening.

The form of Jupiter, like that of the Earth, is an oblate spheroid, the equatorial diameter being to the polar as 14 to 13. This is occasioned by his extraordinary rapid motion on his axis; for the fluids, together with the light particles which they can carry or wash away with them, recede from the poles which are at rest towards the equator, where the motion is quickest.

The axis of Jupiter is so nearly perpendicular to his orbit, that he has no sensible change of seasons, which is very wisely ordered by the Author of Nature; for if this were not the case, just as many degrees round each pole, as the axis was inclined, would be in darkness for nearly six months.

To Jupiter the sun only appears 1-28th part of the size he does to the Earth, and the light and heat he receives from that luminary are in the same proportion. But he is in some measure compensated for this want by the quick return of the sun, occasioned by the prodigiously rapid motion round his axis; and, in order to supply him with additional light, he is accommodated with four satellites, or moons, which revolve round him.

> Four second planets his dominion own,
> And round him turn, as round the earth the moon.
>
> BLACKMORE.

The discovery of these satellites were made by Galileo in 1610; and they may be considered as one of the first fruits of the invention of the telescope. They cannot be seen by the naked eye, but are distinctly visible with a telescope of a moderate power. Their relative situation with regard to Jupiter, as well as to each other, is constantly changing. Sometimes they all may be seen on one side of Jupiter, and sometimes all on the other; but most frequently some of them on one side, and some on the other. They are designated by their distances from Jupiter, that being called the *first* whose distance from Jupiter is least, when at the greatest elongation, and so on with the others. They are of very different magnitudes, some of them being greater than our earth, while others are not so large as the moon. Their apparent diameters being insensible, their real magnitudes cannot be exactly measured. The attempt has been made by observing the time they take to enter into the shadow of Jupiter; but there is a great discordance in the observations which have been made to ascertain this circumstance; and, of course, the results of these observations must also be very discordant. The *third*, how-

ever, is the greatest; the *fourth* is the second in magnitude; the first, the third in magnitude; and the second is the least. The first goes round Jupiter in 1 day, 18 hours, 27 minutes, 33 seconds, at the distance of 5⅓ times the semidiameter of Jupiter; the second in 3 days, 13 hours, 13 minutes, 42 seconds, at the distance of 9 semidiameters; the third in 7 days, 3 hours, 42 minutes, 33 seconds, at the distance of 14⅓ semidiameters; and the fourth in 16 days, 16 hours, 32 minutes, 8 seconds, at the distance of 25⅓ semidiameters of Jupiter. The three nearest of these satellites fall into the shadow of Jupiter, and are eclipsed in every revolution; but the orbit of the fourth is so much inclined, that it is not eclipsed every time it is in opposition to Jupiter. Sometimes the satellites pass between us and Jupiter, and then their shadows are seen crossing his disc. From this it is evident that both Jupiter and his satellites are opaque bodies, which derive their light from the sun; and as they are always observed to move eastward when they are entering into the shadow of Jupiter, and westward when they pass over his disc, it is evident that their motion is progressive, or in the same direction with the motion of the primary planets round the sun. The eclipses of these satellites were not only the cause of that most curious discovery made by Roemer in the year 1675, that light required 8 minutes 13 seconds to pass from the sun to the earth; but they are of the greatest use in determining the longitude of places on the earth, because this difficult and important problem can be more easily and accurately solved by means of these eclipses than by any other method yet known. As a proof of these satellites passing into the shadow of Jupiter when they disappear, we may remark, that the satellite which is eclipsed always disappears on that side of Jupiter which is opposite to the sun, or where his shadow falls. We may also remark, that the side of the satellite which is nearest to the disc of the planet is first eclipsed; and that the duration of the eclipse corresponds exactly to the time necessary for the satellite to pass through the shadow. The form of the orbit of the satellites is found to be nearly circular, especially that of the 1st, 2d, and 3d; and the velocity of their motions nearly uniform.

In consequence of observing periodical changes in the intensity of the light of the satellites, Dr. Herschel inferred that they revolve on their axis, and that the period of their rotation is equal to the time of their revolution round Jupiter.

OF SATURN. ♄

But farther yet the tardy Saturn lags,
And seven attendant luminaries drags;
Investing with a double ring his pace,
He circles through immensity of space

The planet Saturn moves in a still more extensive orbit than that of Jupiter, his distance from the sun being about 903 millions of miles. The period in which he performs his sidereal revolution round the sun,

is 10758 days, 23 hours, 16 minutes; the velocity of his motion is therefore about 18,000 miles per hour.

The time he takes to revolve on his axis is ten hours sixteen minutes.

The diameter of Saturn is 79,491 miles, which is about ten thousand less than that of Jupiter. His shape is that of an oblate spheroid, like that of Jupiter, but still more elliptical, the equatorial diameter being to the polar as 12 to 11.

Saturn shines with a very feeble light compared with that of Jupiter, on account of his great distance from the sun. But notwithstanding this he is one of the most extraordinary and engaging objects which astronomy presents to our view. He is distinguished from all the other planets by a broad luminous ring which surrounds his body. This extraordinary phenomenon was discovered about the end of the 17th century, by the astronomer Huygens. When seen through a good telescope, the ring appears double, and is seen to cast a deep shadow on the planet Dr. Herschel was of opinion that the ring has a motion, an axis which is at right angles to its own plane; and that it is completed in the same time with that of the planet itself, that is, in a little more than 10 hours. The plane of the ring coincides with the equator of Saturn. but it makes an angle with the ecliptic of about 30°, and remains always parallel to itself. The upper surface of it will, therefore, be illuminated during half the period of Saturn's revolution round the sun, or about 15 years, and the under surface during the other half of the period. For the same reason the plane of the ring must, in the course of one revolution, twice intersect the plane of the ecliptic, and then the thin edge only of the ring being illuminated, it will be invisible while it remains in that position. When the ring is seen under the most favourable circumstances, it has the appearance of an eclipse, the breadth of which is nearly half its length; but after this it gradually becomes narrower, till at length its farthest arc is hid behind the planet, and the nearer is confounded with it. It is in this situation that it has been seen to cast a shadow upon the disc of the planet; from which it is inferred that it is an opaque body, illuminated by the sun. Although we have stated that the ring is invisible when its edge is turned to the earth, on account of the quantity of light which it then reflects being so small that it cannot be observed through ordinary telescopes; yet with instruments of very great magnifying power it never ceases to be visible. Dr. Herschel says, that when he observed with his 40-feet reflector he could always observe the ring. Although the ring encompasses Saturn, yet it is every where separated from him; for stars have been seen between it and the planet. The apparent breadth of the ring is about one-third that of the planet, and about equal to the distance of Saturn from its inner edge. The ring does not appear uniform, for it seems divided by a dark line going all round, concentric with the outer and inner edge, and forming two rings, of which the outermost is only about one-third the breadth of the other.

Muse! raise thy voice, mysterious truth to sing,
How o'er the copious orb a lucid ring,
Opake and broad, is seen its arch to spread
Round the big globe at stated periods led;
Perhaps (it's use unknown) with gather'd heat
To aid the regions of that gelid seat,
The want of nearer Phœbus to supply,
And warm with reflex beams his summer sky,
Else might the high plac'd world expos'd to frost,
Lie waste, in one eternal winter lost. BROWN.

The distance of Saturn from the sun being nearly ten times greater than that of the earth, he can only enjoy about one-ninetieth part of the heat and light which the earth enjoys. Besides the ring just described, Saturn is attended by *seven* satellites, which in a great measure compensate for the scantiness of light that he derives from the sun.

The fourth satellite is sometimes called the Huygenian satellite; it was discovered by Huygens, in 1655; the first, second, third, and fifth were discovered, some years afterwards, by Cassini; and the sixth and seventh were discovered by Dr. Herschel in 1789. The numbers denote the order in which they were discovered, except in the case of the fourth, and not their distances from the primary, as in the case of Jupiter. When ranked in the order of their distance from Saturn they must be arranged thus: the sixth, seventh, first, second, third, fourth, fifth; and if this order be inverted, they will then be ranked according to their comparative brightness, with the exception of the fifth, which never equals the fourth in splendour. The orbits of all of them are nearly circular; and with the exception of that of the fifth, nearly in the plane of the ring. But the orbit of the fifth is considerably more inclined to the ecliptic; and when this satellite reaches its greatest western elongation, it exceeds all the others in splendour; but when it arrives at its greatest eastern elongation, it disappears altogether, and continues invisible for half the time it requires to perform its revolution round its orbit. This appearance is not occasional, for it always occurs when the satellite is in the same position. Hence it is inferred, that this satellite, like our moon, revolves on its axis in a period exactly equal to the time of its revolution round Saturn.

The periodical revolutions and distance of these satellites from the body of Saturn, expressed in semi-diameters of that planet, as well as in miles, are exhibited in the following table:

Satellites.	Periods.				Distances in	
					Semi-diameters	Miles
	d.	h	′	″		
1	1	21	18	26	$4\frac{1}{3}$	170,000
2	2	17	44	51	$5\frac{1}{2}$	217,000
3	4	12	25	11	8	303,000
4	15	22	41	14	18	704,000
5	79	7	54	37	54	2 050,000
6	1	8	53	9	$3\frac{1}{3}$	135,000
7	0	22	37	30	$2\frac{2}{3}$	107,000

These satellites are all so small, and at such a distance from the earth, that they cannot be seen unless with very powerful telescopes.

The surface of Saturn, like that of Jupiter, is diversified by a number of belts, or regular stripes. Huygens observed five belts, which were nearly all parallel to the equator of Saturn. Dr. Herschel likewise observed several belts, which are in general parallel to the ring. On the 11th of November, 1793, he observed a bright, uniform, and broad belt, close to which was a broad and dark one, divided by two narrow white streaks; so that he saw the same number of belts as Huygens, three of which were dark and two light. These belts cover a larger zone of the disc of Saturn, than those of Jupiter occupy upon his surface.

The orbit of Saturn was long considered as the boundary of the solar system, except the cometary orbits, which were believed to stretch far beyond it. The discovery of the planet Uranus has, however, extended the system far beyond the limits formerly assigned to it.

OF URANUS, OR HERSCHEL. ♅

Last, outmost Herschel walks his frontier round
The boundary of worlds; with his pale moons
Faint glimmering through the darkness night has thrown,
Deep dyed and dead, o'er this chill globe forlorn:
An endless desart, where extreme of cold
Eternal sits, as in his native seat,
On wintry hills of never thawing ice;
Such Herschel's earth.

A new planet was discovered by Dr. Herschel on the 13th March, 1781, and called by him *Georgium Sidus*, out of respect to his Majesty George III.; but some astronomers have given it the name of Herschel, after its discoverer, while others have given it the name of *Uranus*, which is the name now given to it in almost every work on astronomy, and seems to be conformable to the manner of naming the other planets, that is, from the heathen mythology. Besides, if the situation of this planet in the system be considered, the name *Uranus* is quite apposite. For as Saturn's orbit includes that of Jupiter, and he bears the name of Jupiter's father, there seems an equal propriety in calling the next planet, whose orbit includes that of Saturn, by the name of Uranus, Saturn's father.

The mark or character by which Uranus is distinguished in astronomical works is ♅. The orbit of this planet is situated far beyond that of Saturn, being at the immense distance of 1,822,000,000 miles from the sun. The time of its sidereal revolution round that luminary is said to be 30,688 days, 17 hours. His diameter is about $4\frac{1}{2}$ times greater than that of the earth, or nearly 35,000 English miles.

The distance of this planet is so great, that it cannot be seen by the naked eye, except when the atmosphere is very clear, and then

it appears like a star of the 6th magnitude. It had been observed by Flamsead and Mayer; but was considered by them as a fixed star, and put down in catalogues as such. Long before the discovery of this planet, some disturbances and deviations in the motions of Jupiter and Saturn were observed by astronomers, which they could only account for on the supposition that there existed some planet still more distant from the sun than Saturn. But this can only be considered in the light of mere conjecture. For it is to the indefatigable industry and exertions of Dr. Herschel, that we are indebted for the discovery of this planet, and all the important particulars connected with its motion.

Uranus is at such an immense distance from the sun, that the light he receives from that luminary must be very small indeed; but this want is in a great measure supplied by six satellites which revolve round him, all of which were discovered by Dr. Herschel. The first and fourth he discovered in January 1787; and the other four in 1790 and 1794.

The orbits of all the satellites are nearly in the same plane, and almost at right angles to the orbit of Uranus; but what is rather extraordinary, the motion of these satellites is retrograde, or directly the reverse of the other planets and satellites.

The distances and periodic times of the satellites are as in the following table:

Sat	Distances in Semi diameters of Uranus	Periodic times.		
		d.	h.	m.
1	13·120	5	21	25
2	17·022	8	17	1
3	19·845	10	23	4
4	22·752	13	11	5
5	45·507	38	1	49
6	91·008	107	16	40

Eclipses of the satellites sometimes take place; but these can only be seen when Uranus is near his opposition. This happened in the year 1799, and also in 1818; but they can only be discerned by the most powerful telescope, and when the sky is perfectly clear.

THE PLANETS, AS SEEN THROUGH A TELESCOPE.

If eager still in Nature's book to pry,
Thou should'st the Astronomic tube apply;
And trace with careful eye the wide inane,
The Comet's blaze, and Planetary train:
Then shalt thou mark the various systems roll,
And learn the laws that regulate the whole. CARLY

Although many of the phenomena mentioned in the foregoing pages have been discovered by means of the telescope, yet this most valuable instrument has been the means of accomplishing many other splendid

discoveries, which could not be noticed, consistently with the plan of this work, at an earlier period.

The telescope was first turned to the heavens by the celebrated astronomer and philosopher, Galileo; hence it has been aptly enough styled the Galilean tube.*

> ——————— By whose aid are seen
> The planetary phases, the bright cohort
> Of secondary worlds; and countless suns,
> Which, hid in the immensity of space,
> Ne'er visited the sight: from whom we learn
> The eclipse in time and quantity exact;
> And trace the parallax, that wondrous clue,
> By which the distance and the magnitude
> Of the celestial spheres are known on earth. EUDOSIA.

No astronomer has ever done more to improve the telescope, or made more observations and discoveries in the heavens by means of this most amusing and useful instrument, than the late Dr. Herschel.† It may therefore be gratifying to hear the Doctor's observations respecting the requisites which this instrument ought to possess, in order to enable the observer to make accurate and minute observations on any of the celestial bodies.

In stating the result of a series of observations on the satellites of Uranus, or the Georgian planet, as the Dr. terms it, he says, "The great distance of this planet renders an attempt to investigate the movements of its satellites a very arduous undertaking; for their light, having to traverse a space of such vast extent before it can reach us, is so enfeebled, and their apparent diameter so diminished, that an instrument, to be prepared for viewing them, must be armed with the double power of magnifying and of penetrating into space."—"The first of these properties," continues the Dr. "seems not to be generally understood: the question how much a telescope magnifies admits of various answers. To resolve it properly, we ought, in all circumstances, to consider how far the magnifying power of a telescope is supported by an adequate quantity of light; for without it, even the highest power and distinctness cannot be *efficient*. This is abundantly confirmed when a ten-feet reflector is directed to the Georgian planet; for with none of its highest powers can we possibly ascertain even the existence of the satellites.

"Since, then, it is absolutely necessary that the power of magnifying should be accompanied with a sufficient quantity of light to reach the satellites of this remote planet, it may be useful to cast an eye upon the action of a power which is become so essential. Its advantages and its inconveniences must equally be objects of consideration.

"A very material inconvenience is, that mirrors which must be large in order to grasp much light, must also be of a great focal length; and that in consequence of this we must submit to be encumbered with a large apparatus.

* See page 9 of the Supplement to this Work.

† As he is better known by the little Dr. than Sir William Herschel, we retain the former.

"The forty-feet telescope having more light than the twenty-feet one, which I frequently use, it ought to be explained why I have not always used it in making my observations on the satellites of the Georgian planet. Of two reasons that may be assigned, the first relates to the apparatus and the nature of the instrument. The preparations for observing with it take up much time, which in fine is too precious to be wasted in mechanical arrangements. The temperature of the air for observations that must not be interrupted, is often too changeable to use an instrument that will not easily accommodate itself to the change; and since this telescope, besides the assistant at the clock and writing-desk, requires moreover the attendance of two workmen to execute the necessary movements, it cannot be convenient to have every thing prepared for occasional lucid intervals between flying clouds that may chance to occur; whereas in less than ten minutes the twenty-feet telescope may be properly adjusted and directed, so as to have the planet in the field of view.

"In the next place I have to mention, that it has constantly been rule with me, not to observe with a larger instrument when a smaller would answer the intended purpose. To use a manageable apparatus saves not only time and trouble, but what is of still greater consequence, a smaller instrument may comparatively be carried to a more perfect degree of action than a larger one; because a mirror of less weight and diameter may be composed of a metal which will reflect more light than that of a larger one; it will also accommodate itself sooner to a change of temperature; and when it contracts tarnish, it may with less trouble be repolished."

After describing the effects of different kinds of eye-glasses, the Dr. states that the magnifying power by which the satellites of Uranus were discovered was only 157; and that he constantly used the same power in his sweeps of the heavens, and found it to be very *effective* for the discovery of faint nebulæ, and minute clusters of stars, but hardly sufficient to show the satellites steadily.

The higher powers of 2400, 3600, and 7200, were only employed to scrutinize the closest neighbourhood of the planet, in order to discover additional satellites; but from the appearance of the known satellites with these powers, they were found too indistinct to be used.*

It has already been remarked, that both Mercury and Venus exhibit all the various phases of the moon. This, however, cannot be perceived without the aid of a very good telescope. But with this assistance the eye can very distinctly discern all the variety of forms in these two planets, which can be so easily perceived in the moon by the naked eye. After their inferior conjunction, that is, when first seen in the morning, rising a little before the sun, they exhibit the form of a crescent. When they have attained their greatest western elongation, they appear nearly half illuminated. As they return towards the sun, their disc becomes more and more illuminated, till they reach their superior conjunction, when it is

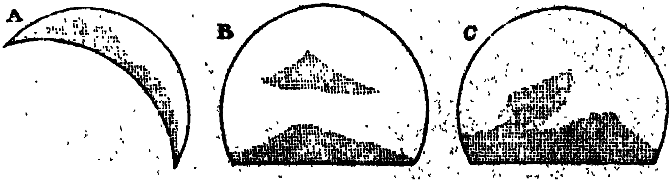
* The telescopes here mentioned are of the *reflecting* kind, the mirrors of which are metal, or rather an alloy of various metals. The great mirror of the 40-feet telescope is four feet in diameter, and weighs above 2000 pounds.

completely illuminated; but being on the opposite side of the sun with respect to the earth, they are lost in his rays. When they begin to be seen in the evening, their disc appears gibbous, or more than half; and when they have reached their greatest elongation, it again appears about half enlightened. In their return to the sun, the luminous disc continues to diminish till they arrive at their inferior conjunction, and then their dark side is completely turned towards the earth.

In the interval between the disappearing of these planets in the evening, and their re-appearing in the morning, they sometimes pass over the sun in the form of a dark spot. See page 25. This appearance would happen at every inferior conjunction of Mercury and Venus, and their passage would be right across his centre, if their orbits were co-incident with the ecliptic. But on account of both their orbits being inclined several degrees to the ecliptic, they are never seen to cross the sun's disc but when they are very near any of their nodes at the time of their inferior conjunction, which is very seldom the case. At all other times they pass either above or below the disc of the sun. The transits of Venus succeed each other at the intervals of eight and one hundred years alternately.

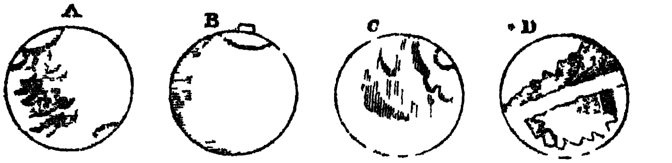
The planet Mercury is so much immersed in the sun's rays, that few observations can be made upon him. It is, therefore, almost impossible to observe points of unequal splendor on his disc; and yet certain periodical inequalities have been observed in the horns of the disc. This circumstance has led some astronomers to conclude that Mercury has a revolution on his axis as well as the planets Venus, Mars, Jupiter, and Saturn, each of which has had its revolution on its axis determined by the same means; namely, the motion of certain spots, distinguished by the colour or intensity of their light from the other parts of the planetary disc.

The astronomer Shroeter, by continued observations on the horns of Venus, and attending to the variations in the appearance of some luminous points near the edges of the unenlighted parts, has not only ascertained that Venus has a revolution on its axis, but that its surface is diversified with mountains of very great height. The following figure, A, represents Venus according to Herschel, and B and C according to Shroeter; they are, however, inverted.



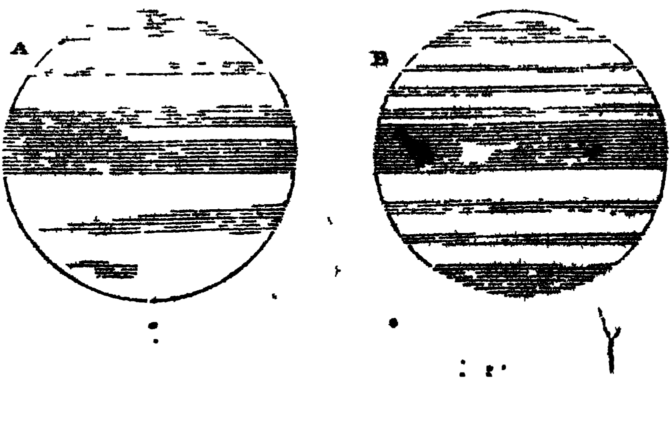
The extreme difficulty, however, of seeing the spots on this planet even with the best telescopes, in our climate, prevents such observations from being so often repeated as could be wished. In point of brilliancy, Venus surpasses all the other planets. On some occasions it is so bright as to be seen in full day by the naked eye.

The gibbous appearance, and spheroidical figure of Mars, could never have been discovered without the assistance of very powerful telescopes; for, as we have already remarked, the true figure of this planet was unknown till the time of Dr. Herschel. But the industry and ingenuity of this celebrated astronomer, in constructing telescopes of the most powerful kind, and making observations with them, has not only ascertained the real figure of this planet, but also of almost all the other planets; and by the spots which he discovered near the poles of Mars, he has been enabled to settle the inclination of its axis to the plane of its equator, and consequently to ascertain its change of seasons. The following figures, A, B, C, and D, represent this planet as seen by Dr. Herschel, with his best telescopes:—



From these discoveries it appears, that the analogy between Mars and the Earth is greater than between the Earth and any other planet of the solar system. Their diurnal motion is nearly the same, the obliquity of their respective ecliptics, on which the seasons depend, are not very different; and of all the superior planets, the distance of Mars from the Sun is by far the nearest alike to that of the Earth; nor is the length of its year very different from ours, when compared with the years of Jupiter, Saturn, and Uranus.

The telescopic appearance of the planet Jupiter having been pretty fully treated of at page 36, little more remains to be said respecting it. With a telescope of a very moderate power, the disc of Jupiter appears nearly as large as the Moon; and though the surface be diversified by regular and parallel belts, yet it appears much smoother than that of the Moon. The following figures, A and B exhibit the appearance of this planet as seen by Herschel with his best telescope.



The satellites which attend Jupiter cannot be perceived without the aid of a telescope which magnifies at least thirty times, but with one which magnifies fifty times, they may be seen most distinctly. The telescope by which they were first discovered magnified thirty two times; but it required many observations, and great attention to their relative situations, to distinguish them from small stars with such a small power. When the satellites are about to be hid behind the body of Jupiter, they are often observed to disappear, though at some *distance* from the planet; and the third and fourth sometimes re-appear on the same side of the disc.

The only cause which can be assigned for these disappearances is the conical shadow which Jupiter casts behind him; for the satellites are always observed to disappear on that side of the disc opposite to the sun, and consequently on the same side to which the conical shadow is projected.

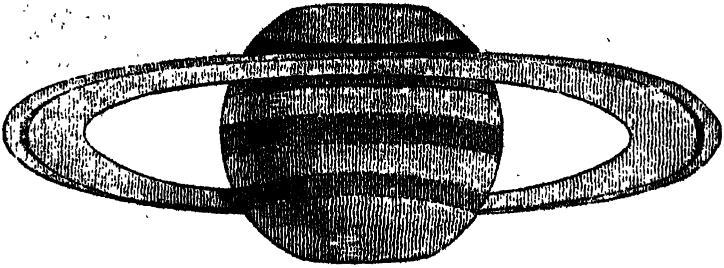
Another proof of this being the cause is, that they are eclipsed nearest to the disc when Jupiter is nearest to his opposition; and the duration of these eclipses answers precisely to the time which they should employ to pass through the conical shadow of Jupiter.*

Another singular appearance in the satellites has been remarked by Dr. Herschel; which is, that the same satellite is more luminous at one time than another, and that the period of these changes is for each satellite the same with the time of its revolution about Jupiter. hence he has inferred, that each of the satellites revolves on its axis in the same time that it revolves round Jupiter, which is well known to be the law that the moon observes in its revolution.

Of all the wonderful and extraordinary appearances exhibited by the heavenly bodies, which belong to the solar system, when viewed by a powerful telescope, those which the planet Saturn exhibits are the most to be admired.

The appearance of this planet, when examined with a powerful telescope, is not only singular and wonderfull, but it is one of the most beautiful and interesting sights which are to be seen in the heavens. The planet itself, with its belts and spots, is an interesting object; but when viewed at a time that the ring is most conspicuous, the effect is peculiarly grand and beautiful. But, having already given an account of the appearance and changes which the ring undergoes, as well as a description of the other phenomena belonging to this extraordinary planet, little remains to be said respecting it here. We shall, however, give a representation of this planet, as observed by Dr. Herschel, on various occasions, with his most powerful telescope.

* When Jupiter, or any of the *superior* planets, are in opposition to the sun, they are then at least distance from the earth, and at their greatest when in conjunction with him, but the contrary is the case with the *inferior* planets.



On account of the great distance of this planet from the sun, it appears much fainter than Jupiter. With the naked eye it can scarcely be discovered, except when the sky is very clear.

The real form of the ring has not yet been accurately determined. When seen in the most favourable position, it appears of an oval or ecliptic form; but supposing it circular, its breadth has been determined to be about one-third of the diameter of the planet.

The planet Uranus, being so immensely distant from the earth, and from the sun, which illuminates him, he cannot be discovered at all without the assistance of the *telescope;* of course, all that we know of this planet we owe to the powerful telescopes and persevering industry of its discoverer, Dr. Herschel. But, having already stated the result of the Doctor's observations on this planet, at page 29, as well as his more recent observations on its satellites, at the beginning of this article, nothing remains to be said of them here.

OF COMETS.

> Hast thou ne'er seen the Comet's flaming flight?
> Th' illustrious stranger, passing, terror sheds
> On gazing nations, from his fiery train,
> Of length enormous; takes his ample round
> Through depths of ether; coasts unnumber'd; worlds
> Of more than solar glory; doubles wide
> Heaven's mighty cape, and then revisits earth,
> From the long travel of a thousand years.
>
> YOUNG.

Besides the planets just described, which are always nearly at the same distance from the sun, and within our view, there are other bodies belonging to the solar system called Comets, which seldom come within our view. In their appearance, the comets are very remarkable, being generally surrounded by a faintly luminous vapour, to which the name of *coma* has been given. As the comet approaches the sun, the coma becomes brighter, and at length shoots out into a long train of luminous transparent vapours, which always keep in a direction opposite to the sun, and is called the tail of the comet. When a comet makes its appearance, it is only for a very

short period, seldom exceeding a few months, and sometimes only a few weeks. Instead of moving from *west* to *east*, like the planets, in orbits making small angles with the ecliptic, they are observed to cross it at all angles. Their progress among the fixed stars is in general more rapid than that of the planets, and their change of apparent magnitude is much more remarkable. When a comet retires from the sun, its tail decreases, and nearly resumes its first appearance. Those comets which never approach very near the sun have nothing but a coma, or nebulosity round them, during the whole time of their continuance in view.

The tail of a comet is always transparent; for the stars are often distinctly visible through it; and it has even been said, that, on some occasions, they have been seen through the nucleus, or head. The length and form of the tail are very different: sometimes it extends only a few degrees, at others it extends more than 90 degrees. In the great comet that appeared in the year 1680, the tail subtended an angle of 70°; and the tail of the one which appeared in 1618, an angle of 104°. The tail sometimes consists of diverging streams of light; that of the comet which appeared in the year 1744 consisted of six, all proceeding from the head, and all a little bent in the same direction.

The tail of the beautiful comet which appeared in 1811 was composed of two diverging beams of faint light, slightly coloured, which made an angle of 15° to 20°, and sometimes much more. Both of these were a little bent outward, and the space between them was comparatively obscure.

The apparent difference in the length and lustre of the tail of comets has given rise to a popular division of these singular bodies into three kinds; viz. *bearded, tailed,* and *hairy* comets; but this division rather relates to the several circumstances of the *same* comet, than to the phenomena of different ones. Thus, when the comet is *east* of the sun, and moves *from* him, it is said to be *bearded*, because the light precedes it in the manner of a beard; when the comet is *west* of the sun, and sets after him, it is said to be *tailed*, because the train of light follows it in the manner of a tail; and when the sun and comet are diametrically opposite, the earth being between them, the train or tail is all hid behind the body of the comet, except the extremities, which, being broader than the body of the comet, appear to surround it like a border of *hair*, and on this account it is called hairy.

But there have been several comets observed, whose disc was as clear, round, and well defined, as that of Jupiter, without either tail, beard, or coma. The magnitude of comets has been observed to be very different; many of them without their coma have appeared no larger than stars of the first magnitude; but some authors have given us accounts of others, which appeared much greater. Such was the one that appeared in the time of the Emperor Nero, which, as Seneca relates, was not inferior in apparent magnitude to the sun himself. The comet which Hevelius observed, in the year 1652, did not seem to be less than the moon, though it was deficient in splendor; for it

had a pale, dim light, and appeared with a dismal aspect. Most Comets have dense and dark atmospheres surrounding their bodies, which weaken the sun's rays that fall upon them; but within these appears the nucleus, or solid body of the Comet, which, when the sky is clear, will often give a more splendid light.

Respecting the nature of these singular and extraordinary bodies, philosophers and astronomers in all ages and countries have been very much divided in their opinions. The vulgar have, however, invariably considered them as *evil omens*, and forerunners of war, pestilence, famine, &c.; and to adopt the language of an old poet:

> ———" The blazing star was viewed—
> Threat'ning the world with famine, plague, and war;
> To princes death; to kingdoms many crosses;
> To all estates inevitable losses;
> To herdsmen rot; to ploughmen hapless seasons;
> To sailors storms; to cities civil treasons."

The Chaldeans, who were eminent for their astronomical researches, were of opinion, that Comets were lasting bodies, which had stated revolutions as well as the Planets, but in orbits considerably more extensive, on which account they are only visible while near the earth, but disappear again, when they ascend into the higher regions.—Pythagoras taught, that Comets were wandering stars, disappearing in the superior parts of their orbits, and becoming visible only in the lower parts of them. Some of the ancient philosophers supposed, they were nothing else but a reflection of the beams from the sun or moon, and generated as a rainbow; others supposed they arose from vapours and exhalations. The illustrious Aristotle was of opinion they were *meteors*. Modern philosophers have been equally perplexed as their predecessors in accounting for the nature of these magnificent celestial appearances. The eccentric but learned Paracelsus gravely affirmed that they were formed and composed by angels or spirits, to foretel some good or bad events. Kepler, the celebrated astronomer, asserted that Comets were monsters, and generated in the celestial spaces, by an animal faculty! The sentiments of Bodin, a learned French writer of the 16th century, were yet more absurd; for he maintained, that Comets are spirits which have lived upon the earth innumerable ages, and being at last arrived on the confines of death, celebrate their last triumph, or are called to the firmament like shining stars!

James Bernoulli, a celebrated Italian philosopher, formed a rational conjecture relative to Comets in viewing them as the satellites of some very distant planets, invisible on the earth on account of its distance, as were also the satellites, unless when in a certain part of their course. Tycho Brahe, the illustrious but unfortunate philosopher of Denmark, supported a true hypothesis on this subject; he averred, that a Comet had no sensible diurnal parallax, and therefore was not only far above the regions of our atmosphere, but much higher than the moon; that few have come so near the earth as to have any diurnal parallax, yet all Comets have an *annual parallax*, the revolution of the earth in their orbit, causes their apparent motion to be

very different from what it would be, if viewed from the sun, which demonstrates that they are much nearer than the fixed stars which have no such parallax.

Descartes advanced aother opinion, which is, that Comets are only stars, that were formerly fixed like the rest, but becoming gradually covered with *maculæ* or spots, and at length wholly deprived of their light, cannot keep their places, but are carried off by the *vortices** of the circumjacent stars; and in proportion to their magnitude and solidity, moved in such a manner, as to be brought nearer to the orb of Saturn; and thus coming within the reach of the sun's light, are visible.

The absurdity of most of these hypotheses is now proved by the observations which have been made on these bodies, by the celebrated astronomers who have lived since the time of Descartes; and particularly by our countrymen, Dr. Halley and Sir I. Newton. According to the theory of Newton, the Comets are compact, solid, and durable bodies; in fact a species of planets, which move in very oblique and eccentric orbits, in every direction, with the greatest freedom; persevering in their motions even against the course and direction of the planet.

The number of Comets which have been observed and recorded with more or less accuracy, exceed 350; but not one-third of these have been observed with such accuracy as to allow the elements of their orbits to be ascertained.† Dr. Halley, following the theory of Newton, set himself to collect all the observations which had been made on Comets, and calculated the elements of 24 of them. And by computations founded on these elements, he concluded that the Comet of 1682, was the same that had appeared in 1607, 1531, and 1456; that it had a period of 75 or 76 years; and that it might, of course, be expected to appear again about the year 1759, which it actually did. It therefore could be no longer doubted, that the Comet observed in each of these years was the same, although its appearance was very different. When it appeared in 1531, it was of a bright gold colour; in 1607, it was dark and livid; in 1682 it was bright; and in 1759, it was faint and obscure. The return of some of the other Comets is probable, though not certain.

* Descartes supposed that every thing in the universe was formed from very minute bodies called atoms, which had been floating in open space. To each atom he attributed a motion on its axis; and he also maintained that there was a general motion of the whole universe round like a vortex or whirlpool. In the centre of this vortex was the sun, with all the planets circulating round him, at different distances; and that each star was also the centre of a general vortex, round which its planets turned. Besides these general vortices, each planet had a vortex of its own, by which its satellites (if it had any) were whirled round, and any other body that came within its reach!

† The elements of a planet or comet are, 1st. The inclination of the orbit; 2d. The position of the line of the nodes; 3d. The longitude of the perihelion; 4th. The perihelion distance from the sun; 5th. The time when a planet or comet is in its perihelion

The great Comet of 1680, was supposed by Dr. Halley to have a period of 575 years, and to be the same that appeared a little before the death of Julius Cæsar, in the year 44 A.C.; again in the reign of Justinian, in the year 531 P.C.; and in 1106, in the reign of Henry I. At all of these periods, appearances of a great and terrible Comet are recorded, but no such observations have been made on them as to ascertain their *elements*.

The Comet of 1680, just mentioned, approached nearer to the sun than any other that is known. At its perihelion, its distance from the sun was only $\frac{1}{166}$th part of the earth's, or about 572,000 miles, whilst its aphelion distance is stated by Sir I. Newton to be not less than 11,200,000,000 miles. It descended to the sun with a velocity of 880,000 miles per hour, almost perpendicularly, and ascended in the same manner, remaining in sight for four months!

Some Comets have come very near the earth, particularly one which appeared in 1472, and another in 1760. The former of these, it is said, moved over an arc of 120° in one day, and the latter 41° in the same space of time. These extraordinary changes can scarcely be accounted for on any other principle but their proximity to the earth.

It appears that Comets contain very little matter; for in the year 1454, one approached so near the earth, that it is said to have eclipsed the moon; and yet it produced no sensible effects. Neither did those just mentioned. And in 1770 a Comet approached very near to the satellites of Jupiter, without producing any derangement of these bodies.

It has, however, been supposed by some astronomers, that too near an approach of a Comet to any other planet, might be productive of very great changes in the system to which they belong. The celebrated Mr. Whiston and other eminent writers have indulged an idea that the dissolution of this globe by fire will be occasioned by the near approach of a Comet which will cause the general conflagration. This supposition is assuredly worthy of due consideration, and appears founded on the basis of sound reason.

Whatever difference of opinion prevails among the various sects professing the Christian Faith, they all unite in believing that, at the final consummation of all things, a general conflagration will take place, and that this earth will be destroyed by fire. Our Lord, in describing the awful scenes of the last judgment, observes, that "the powers of Heaven shall be shaken," Luke, xxi. 16. Now if a Comet, in its revolution, should approach too near the orbit of another planet, and a derangement of the order of the heavenly bodies ensue, those powers must be shaken. Therefore in this point of view Comets are particularly calculated to impress a serious and religious awe, but not a superstitious fear, on every spectator. They blaze forth in the Heavens, not as signs of approaching events, either of good or evil, but to warn us of the final dissolution of this globe on which we dwell by such a phenomenon. He who hath placed his bow in the cloud to testify that the world shall no more be destroyed by water, has also appointed those extraordinary

bodies to illuminate the firmament, to demonstrate that by the agency of a Comet the earth and all that is therein shall be burnt up.

This hypothesis, supported by so able a mathematician, and learned a man, as Mr. Whiston, while it is in perfect congruity with true philosophical principles, is neither founded on the basis of ignorant superstition or wild enthusiasm, but calculated to promote moral and religious improvement.

At his command affrighting human kind,
Comets drag on their blazing lengths behind:
Nor as we think, do they at random rove,
But in determined times, through long ellipses move:
And though sometimes they near approach the sun,
Sometimes behind our system's orbit run;
Throughout their race they act their Maker's will,
His power declare, his purposes fulfil. BAKER.

The conjectures which have been advanced by several celebrated astronomers respecting the nature and cause of the tail which usually accompanies a Comet, are not only curious, but plausible and ingenious. Tycho Brahe, who was the first that gave the Comets their true rank in the creation, supposed that the tail was occasioned by the rays of the sun passing through the head, or nucleus of the Comet, which he believed to be *transparent*. Kepler thought that it was the atmosphere of the Comet which was driven behind it by the force of the solar rays. Sir Isaac Newton maintained that the tail was a thin vapour, ascending by means of the sun's heat, as smoke does from the earth.* Euler supposes that the tail is produced by the impulse of the solar rays driving off the atmosphere from the Comet. The late Dr. Hamilton, of Dublin, supposes them to be of electric matter.

Notwithstanding the ingenuity and even probability of some of these hypotheses, yet there is little in any one of them to entitle it to preference above the others; and till multiplied observations shall have added to the imperfect knowledge which we at present possess of these bodies, it is perhaps better not to give a decided preference to any of them. For as Dr. Herschel very justly observes, "Many of the operations of Nature are carried on in her great laboratory which we cannot comprehend; but now and then we see some of the tools with which she is at work. We need not wonder that their construction should be so singular as to induce us to confess our ignorance of the method of employing them, but we may rest assured that they are not mere *lusus naturæ*. I allude to the great number of small telescope Comets that have been observed; and to the far greater number still, that are probably much too small for being noticed by our most diligent searchers after them. Those six, for

* It is evident that this hypothesis is founded on the supposition which then prevailed, that the sun was a body of *fire*; but as the truth of this supposition is now doubted by most philosophers, and abandoned by many, the hypothesis of Newton on this subject does not now meet with many advocates.

instance, which my sister has discovered, I can, from examination, affirm, had not the least appearance of any solid nucleus, and seemed to be mere collections of vapours condensed about a centre. Five more that I have also observed, were nearly of the same nature. This throws a mystery over their destination, which seems to place them in the allegorical view of tools, probably designed for some salutary purposes to be wrought by them; and, whether the restoration of what is lost to the sun by the emission of light, may not be one of these purposes, I shall not presume to determine. The motion of the Comet discovered by M. Messier, in June 1770, plainly indicated how much its orbit was liable to be changed, by the perturbation of the planets; from which, and the little agreement that can be found between the elements of the orbits of all the Comets that have been observed, it appears clearly that they may be directed to carry their salutary influence to any part of the heavens."

To shake
Reviving moisture on the numerous Orbs
Through which his long ellipsis winds; perhaps
To lend new fuel to declining Suns,
To light up Worlds and feed th' eternal fire."
THOMSON.

OF THE MOON. ☽

Next to the Sun, the Moon is the most remarkable of all the heavenly bodies, and is particularly distinguished by the periodical changes to which her figure and light are subject.

Among the ancients, Luna ☽, or the Moon, was an object of very great respect. By the Hebrews she was more regarded than the Sun: and it appears they regulated their time by her motions and appearances. The *new* moon, or first day of every month, was observed as a festival among them, which was celebrated with sound of trumpets, entertainments, and sacrifices. In the Bible, the Moon is mentioned under several names, as the Queen of Heaven, the Goddess of the Zidonians, and the abomination of the Zidonians, because she was worshipped by the inhabitants of Zidon or Sidon. The ancient bards and poets have also celebrated the praises of the Moon under various appellations; as Cynthia, Cyllene, Phœbe, Silver Queen of Night, Queen of the Silver Bow, &c.

Sister of Phœbus, gentle queen,
Of aspect mild and ray serene;
Whose friendly beams by night appear,
The lonely traveller to cheer!

The Moon is not a primary planet, but a secondary or satellite, which revolves round the earth, and accompanies it in its annual revolution round the sun. The mean time of a revolution of the Moon round the earth, or the time between two successive conjunctions, is 29 days, 12 hours, 44 minutes; but the time she takes to

perform a revolution round her orbit, is only 27 days, 7 hours, 43 minutes. The former of these periods is called the *Synodical*, and the latter the *Periodical* revolution. The difference between these periods is occasioned by the motion of the earth in the ecliptic; for while the Moon is going round the earth, the earth advances about 29° in the ecliptic, which is nearly 1° per day; and, therefore, the Moon must advance 29° more than a complete revolution round her orbit, before she can overtake the earth, or be again in conjunction with the sun, which will require 2d. 5h., her daily motion being about 13 degrees.

Of all the celestial bodies, the Moon is the nearest to the earth, her mean distance being only 240,000 miles, which is scarcely a four hundred part of the sun's distance from the earth; but her apparent size is nearly equal to that of the sun, she must therefore be a very small body compared with the sun. Her diameter is only about 2161 miles; and, therefore the earth is about $48\frac{1}{3}$ times greater; but the density of the Moon is said to be to that of the earth as 5 to 4, consequently the quantity of matter contained in the earth is only about 39 times that contained in the Moon.

Although the Moon moves over a very considerable portion of her orbit in the course of a day, yet on account of its smallness her hourly motion is only about 2290 miles, which is only about $\frac{1}{30}$th part of the space passed over by the earth in the same time.

But in all her motions, the Moon is subject to great irregularities, which arise from the eccentricity of her orbit, and her proximity to the earth. The eccentricity of her orbit, as determined from the latest and most accurate observations, is 12,960 miles, or nearly $\frac{1}{18}$th part of her mean distance; of course she is about $\frac{1}{9}$th part nearer the earth on some occasions than at others.

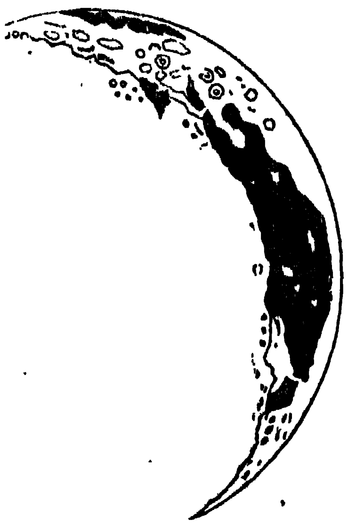
PHASES OF THE MOON.

By Thy command the Moon, as daylight fades,
Lifts her broad circle in the deep'ning shades;
Arrayed in glory, and enthroned in light,
She breaks the solemn terrors of the night;
Sweetly inconstant in her varying flame
She changes still, another yet the same!
Now in decrease by slow degrees she shrouds,
Her fading lustre in a vale of clouds;
Now of increase, her gathering beams display
A blaze of light, and give a paler day.
Ten thousand stars adorn her glittering train,
Fall when she falls, and rise with her again. BROOME.

Although the phases of the Moon are among the most frequently observed phenomena of the heavens, yet they are also among the most wonderful. But on account of the frequency and regularity of the changes in the appearances and situation of this beautiful object, the cause of these phenomena are perhaps less thought of by ordinary observers, than if they were less frequent. The Moon being an

opaque spherical body, which appears luminous only in consequence of reflecting the light of the sun, can only have that side illuminated which is at any time turned towards the sun, the other side remaining in darkness; and as that part of her can only be seen which is turned towards the earth, it is evident that we must perceive different portions of her illuminated, according to her various positions with respect to the earth and sun.

At the time of conjunction, or when the Moon is between the earth and the sun, she is then invisible on the earth, because her enlightened side is then turned towards the sun, and her dark side towards the earth. In a short time after the conjunction, she appears like a fine crescent to the eastward of the sun a little after he sets, as represented by the following figure.



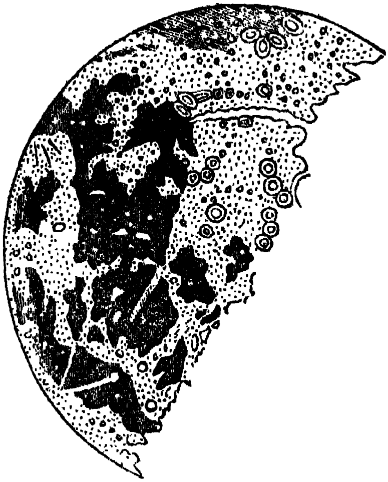
This crescent begins to fill up, and the illuminated part to increase, as she advances in her orbit; and when she has performed a fourth part of a revolution, she appears to be half illuminated, and is then said to be in her first quarter. After describing the second quadrant of her orbit, she is then opposite to the sun, and shines with a round illuminated disc, which is called full moon.* Her appearance at this time is very accurately represented by the following figure.

* At the time of full Moon, the Moon appears to be as large as the sun; for the angle under which the Moon appears when viewed from the earth, is the same as the angle under which the sun appears, and therefore the Moon may hide the sun's whole disc from us, as she sometimes does in solar eclipses, which see.

It is necessary, however, to remark, that the Moon does not appear perfectly round when she is full in the highest or lowest part of her orbit; because we have not a full view of her enlightened side at that time. When *full* in the *highest* part of her orbit, a small deficiency appears on her lower edge; and the contrary, when *full* in the *lowest* part of her orbit.

After the full she begins to decrease gradually as she moves through the other half of her orbit; and when the eastern half of her only is enlightened, she is said to be in her third quarter, and has the following appearance: thence she continues to decrease until she again disappears at the conjunction, as before.*

* These various phases may be satisfactorily and pleasantly illustrated, by placing a lighted candle on a table to represent the sun, and a small ball at some distance from it to represent the earth, and then carrying a smaller ball round it, to represent the moon revolving round the earth.



Between the third quarter and change, the Moon is frequently visible in the forenoon, even when the sun shines; and then she affords us an opportunity of seeing a very agreeable appearance, wherever we find a globular stone above the level of the eye, as suppose on the top of a gate. For, if the sun shines on the stone, and we place ourselves so as the upper part of the stone may just seem to touch the point of the Moon's lowermost horn, we shall then see the enlightened part of the stone exactly of the same shape with the Moon; horned as she is, and inclined the same way to the horizon. The reason is plain; for the sun enlightens the stone the same way as he does the Moon: and both being globes, when we put ourselves into the above situation, the Moon and stone have the same position to our eyes; and therefore we must see as much of the illuminated part of the one as of the other.

The position of the Moon's cusps, or a right line touching the points of her horns, is very differently inclined to the horizon at different hours of the same days of her age. Sometimes she stands, as it were, upright on her lower horn, and then such a line is perpendicular to the horizon; when th's happens, she is in what the astronomers call *the Nonagesimal Degree*; which is the highest point of the ecliptic above the horizon at that time, and is 90 degrees from both sides of the horizon where it is then cut by the ecliptic. But this never happens when the Moon is on the meridian, except when she is at the very beginning of Cancer or Capricorn.

The inclination of that part of the ecliptic to the horizon in which the Moon is at any time when horned, may be known by the position of her horns; for a right line touching their points is perpendicular to the ecliptic. And as the angle which the Moon's orbit makes with

the ecliptic can never raise her above, nor depress her below, the ecliptic, more than two minutes of a degree, as seen from the sun, it can have no sensible effect upon the position of her horns. Therefore, if a quadrant be held up, so as one of its edges may seem to touch the Moon's horns, the graduated side being kept toward the eye, and as far from the eye as it can be conveniently held, the arc between the plumb-line and that edge of the quadrant which seems to touch the Moon's horns, will shew the inclination of that part of the ecliptic to the horizon. And the arc between the other edge of the quadrant and plumb-line, will shew the inclination of a line, touching the Moon's horns, to the horizon.

These various phases plainly demonstrate that the Moon does not shine by any light of her own; for if she did, being globular, she would always present a fully illuminated disc like the sun. That the Moon is an opaque body, is not only proved from her phases, but also by the occultation of stars, for her body often comes between the earth and a star, and while she is passing it, the star is hid from our view.

MOTIONS OF THE MOON.

> The neighbouring moon her monthly round
> Still ending, still renewing, through mid heaven,
> With borrowed light her countenance triform;*
> Hence fills and empties to enlighten th' earth,
> And in her pale dominion checks the night. MILTON.

It has already been remarked, that the motions of the Moon are very irregular. The only equable motion she has, is her revolution on her axis, which is completed in the space of a month, or the time in which she moves round the earth. This has been determined by the important and curious circumstance, that she always presents the *same face* to the earth, at least with very little variation. But as her motion in her orbit is alternately accellerated and retarded, while that on her axis is uniform, small segments on the east and west sides alternately appear and disappear. This occasions an apparent vibration of the Moon backwards and forwards, which is called her *libration* in longitude.

A little more of her disc is also seen towards one pole, and sometimes towards the other, which occasions another wavering or vacillating kind of motion, called the *libration* in latitude. This shows that the axis of the Moon is not exactly, though nearly, perpendicular to the plane of her orbit; for if the axis of the Moon were exactly perpendicular to the plane of her orbit, or if her equator coincided with that plane, we should perceive no other libration than that in longitude.

When the place of the Moon is observed every night, it is found

* Increasing with horns towards the east; decreasing with horns towards the west; and at the *full*.

that the orbit in which she performs her revolutions round the earth, is inclined to the ecliptic at an angle of 5° 9′ at a mean rate; this angle is not only subject to some variation, but the very orbit itself is changeable, and does not always preserve the same form: for though it is elliptical, or nearly so, with the earth in one of the foci, yet its eccentricity is subject to some variation, being greater when the line of the *apsides* coincides with that of the *syzygies*, and least when these lines are at right angles to each other. But the eccentricity is always very considerable, and, therefore, the motion of the Moon is very unequal, for like all other planets, it is quickest in *perigee* and slowest in *apogee*. At a mean rate she advances, in her orbit, 13° 10′ per day, and comes to the meridian about 48 minutes later every day. As the Moon's axis is nearly perpendicular to the plane of the ecliptic, she can scarcely have any change of seasons. But what is still more remarkable, one half of the Moon has no darkness at all, while the other half has two weeks of light and darkness alternately. For the earth reflects the light of the Sun to the Moon, in the same manner as the Moon does to the earth; therefore, at the time of conjunction, or new Moon, one half of the Moon will be enlightened by the Sun, and the other half by the earth: and at the time of opposition, or full Moon, one half of the Moon will be enlightened by the Sun, but the other half will be in darkness. The earth also exhibits similar phases to the Moon to what she does to the earth, but in a reverse order, for when the Moon is *full*, the earth is *invisible* to the Moon; and when the Moon is *new*, the earth will appear to be *full* to the Moon, and so on. It has been already mentioned, that the Moon always presents the same face to the earth, from hence it is inferred, that one half of the Moon can never see the earth at all; whilst from the middle of the other half it is always seen overhead, turning round almost thirty times as fast as the Moon does.

From the circle which limits our view of the Moon, only one half of the earth's side next her is seen, the other half being hid below the horizon of all places on that circle.

To the Moon, the earth seems to be the largest body in the universe, for it appears about thirteen times greater than the Moon does to the earth.

OF THE HARVEST MOON.

It has long been known that the Moon when full, about the time of harvest, rises for several nights nearly at the time of Sun setting; but the cause of this remarkable phenomenon has not been so long known. This appearance was observed by the husbandman long before it was noticed by the Astronomer; and on account of its beneficial effects in affording a supply of light immediately after Sun-set, at this important season of the year, it is called the *Harvest Moon*.

In order to conceive the reason of this phenomenon it must be recollected, that the Moon is always opposite the Sun when she is

full, and of course in the opposite sign and degree of the zodiac. Now the Sun is in the signs Virgo and Libra in August and September, or the time of harvest; and therefore the Moon when full, in these months, is in the signs Pisces and Aries. But that part of the ecliptic in which Pisces and Aries is situated makes a much less angle with the horizon of places that have considerable northern latitude, than any other part of the ecliptic, and therefore a greater portion of it rises in any given time than an equal portion at any other part of it. Or, which is the same thing, any given portion of the ecliptic about Pisces and Aries rises in less space of time than an equal portion of it does at any other part. And as the Moon's daily motion in her orbit is about 13°, this portion of it will require less time to rise about those signs, than an equal portion at any other part of the ecliptic; consequently, there will be less difference between the times of the Moon's rising when in this part of her orbit than in any other.*

At a mean rate the Moon rises 50 minutes later on any evening than she did the preceding evening; but when she is full about the beginning of September, or when she is in that part of her orbit which rises with the signs Pisces and Aries, she rises only about 16 or 17 minutes later than on the preceding evening; consequently, she will seem to rise for a few evenings at the same hour.

Although this is the case every time that the Moon is in this part of her orbit; yet it is little attended to, except when she happens to be *full* at the time, which can only be in August or September.

In some years this phenomenon is much more perceptible than in others, even although the Moon should be full on the same day, or in the same point of her orbit. This is owing to a variation in the angle which the Moon's orbit makes with the horizon of the place where the phenomenon is observed. If the Moon moved exactly in the ecliptic, this angle would always be the same at the same time of the year. But as the Moon's orbit crosses the ecliptic and makes an angle with it of 5° 9′, the angle formed by the Moon's orbit and the horizon of any place is not exactly the same as that made by the ecliptic and the horizon. Some years it is greater, and others less, even at the same time of the year; for it is subject to considerable variations, owing to the retrograde motion of the moon's *nodes*.†

If the ascending node should happen to be in the first degree of Aries, it is evident, that this part of the Moon's orbit will rise with the least possible angle, and, of course, any given portion of it will require less time to rise than an equal portion in any other part of the orbit. The most favourable position of the nodes for producing the most beneficial harvest Moons is, therefore, when the ascending node

* It would tend very much to make this phenomenon understood, if a terrestrial globe were at hand, and rectified for the latitude of London, when reading this description.

† The *nodes*, or points where the moon's orbit crosses the ecliptic, move backward about 19° in a year, by which means they move round the ecliptic in 18 years 225 days.

is in the first of *Aries*, and of course the descending in the first of *Libra*. When the nodes are in these points 13° of the Moon's orbit, about the first of Aries, rises in the space of 16 minutes, in the latitude of London, and consequently, when the Moon is in this part of her orbit, the time of her rising will differ only 16 minutes from the time she rose on the preceding evening. When the Moon is in the opposite part of her orbit, or about the signs Virgo and Libra, which make the greatest angle with the horizon at rising, 13° of her orbit will require 1 h. 15′ to rise, although it were coincident with the ecliptic; and if the nodes be in the points just mentioned, the same portion of the orbit will require 1 h. 20′ to ascend above the horizon of the same place; and so much later will the Moon rise every night for several nights when in this part of her orbit. As the Moon is full in these signs in the months of March and April they may be called *vernal full Moons*.

Those signs of the ecliptic which rise with the greatest angle, set with the least; and those that rise with the least, set with the greatest. Therefore, the vernal full Moons differ as much in their times of *rising*, every night, as the autumnal, or harvest, Moons differ in the times of their *setting*; and they *set* with as little difference of time as the autumnal ones *rise*, supposing the full Moons to happen in opposite points of the Moon's orbit, and the nodes to remain in the same point of the ecliptic.

In southern latitudes, the harvest Moons are just as regular as in the northern, because the seasons are contrary; and those parts of the Moon's orbit about Virgo and Libra, where the *vernal* full Moons happen in northern latitudes, (and the *harvest* ones in southern latitudes) rise at as small an angle at the same degree of *south* latitude, as those about Pisces and Aries in *north* latitude, where the autumnal full Moons take place.

At places near the Equator, this phenomenon does not happen; for every point of the ecliptic, and nearly every point of the Moon's orbit, makes the same angle with the *horizon*, both at rising and setting, and therefore equal portions of it will rise and set in equal times.

As the Moon's nodes make a complete circuit of the ecliptic in 18 years 225 days, it is evident, that when the ascending node is in the first of Aries at any given time, the descending one must be in the same point about 9 years 112 days afterwards; consequently, there will be a regular interval of about 9⅓-years between the *most* beneficial and *least* beneficial harvest Moons.

APPARENT SIZE OF THE MOON.

It has been already remarked at page 55, that the apparent size of the Moon is nearly equal to that of the sun; but the apparent size of the Moon is not always the same, for she is often much nearer the earth at one time than another; hence, it is evident, her apparent magnitude must vary, and that it will be greatest when she is nearest the earth. (See page 54.)

But she appears larger when in the horizon than in the zenith even on the same evening; and yet it may easily be proved, that she is a semi-diameter of the earth, or about 4000 miles, farther from the spectator when she is in the horizon than when she is in the zenith, and consequently ought to appear smaller, which will be found to be really the case if accurately measured.

This apparent increase of magnitude in the *horizontal* Moon, must therefore be considered as an optical illusion: and may be explained upon the well known principle, that the eye in judging of distant objects is guided entirely by the previous knowledge which the mind has acquired of the intervening objects. Hence arise the erroneous estimates we make of the size of distant objects at sea, of objects below us when viewed from great heights, and of objects highly elevated when viewed from below. Now when the Moon is near the zenith, she is seen precisely in this last situation, of course there is nothing near her, or that can be seen at the same time with which her size can be compared; but the *horizontal* Moon may be compared with a number of objects whose magnitude is previously known.

That the Moon appears under no greater an angle (or is not larger) in the horizon, than when she is on the meridian, may be proved by the following simple experiment.

Take a large sheet of paper and roll it up in the form of a tube, of such width as just to include the whole of the Moon when she rises; then tie a thread round it to keep it exactly of the same size, and when the Moon comes to the meridian, where she will appear to the naked eye to be much less, look at her again through the same tube, and she will fill it as completely as she did before.

When the Moon is full and in the horizon, she appears of an *oval* form, with her longest diameter parallel to the horizon. This appearance is occasioned by the refraction of the atmosphere, which is always greatest at the horizon, consequently the lower limb or edge must be more refracted than the upper edge, and therefore these two edges will appear to be brought nearer each other, or the vertical diameter will appear to be shortened; and as the horizontal diameter is very little affected by the refraction, she must appear to have somewhat of an oval shape. The sun is affected in the same manner when in the horizon.

SPOTS, MOUNTAINS, &c. IN THE MOON.

> Turn'd to the sun direct, her spotted disk
> Shows mountains rise, umbrageous dales descend,
> And caverns deep, as optic tube descries. THOMSON.

When the Moon is viewed through a good telescope, her surface appears to be diversified with hills and valleys; but this is most discernable when she is observed a few nights after the change or opposition; for when she is either *horned* or *gibbous*, the edge about the confines of the illuminated part is jagged and uneven.

Many celebrated astronomers have delineated maps of the face of the Moon; but the most celebrated are those of Hevelius, Grimaldi, Riccioli, and Cassini; in which the appearance of the Moon is represented in its different states, from *new to full*, and from *full to new*.

The plate which we have given at page 56, represents the face of the Moon as viewed by the most powerful telescopes, the light or illuminated parts being elevated tracts, some of which rise into very high mountains, while the dark parts appear to be perfectly smooth and level. This apparent smoothness in the faint parts, naturally led astronomers to conclude that they were immense collections of water; and the names given to them, by some celebrated astronomers, are founded on this supposition. For Hevelius distinguished them by giving them the names of the seas on the earth; while he distinguished the bright parts by the names of the countries and islands on the earth. But Riccioli and Langreni distinguished both the dark and light spots, by giving them the names of celebrated astronomers and mathematicians, which is now the general manner of distinguishing them.

That the spots which are taken for mountains and valleys are really such, is evident from their *shadows*. For in all situations in which the Moon is seen from the earth, the elevated parts are constantly found to cast a triangular shadow in a direction from the sun; and on the contrary, the cavities are always dark on the side next the sun, and illuminated on the opposite side, which is quite conformable to what we observe of hills and valleys on the earth. And as the tops of these mountains are considerably elevated above the other parts of the surface, they are often illuminated when they are at a considerable distance from the line which separates the enlightened from the unenlighted part of the disc, and by this means afford us a method of even determining their height.

Previous to the time of Dr. Herschel, some of the lunar mountains were considered to be double the height of any on the earth; but by the observations of that celebrated astronomer, their height is considerably reduced.

For after measuring many of the most conspicuous prominences, he says, "From these observations I believe it is evident, that the height of the lunar mountains is, in general, overrated; and that when we have excepted a few, the generality do not exceed half a mile in their perpendicular elevation."

As the Moon's surface is diversified by mountains and valleys as well as the earth, some modern astronomers say they have discovered a still greater similarity; namely, that some of these are really volcanoes, emitting fire, as those on the earth do. An appearance of this kind was discovered by Don Ulloa in an eclipse of the sun, which happened on the 24th June, 1778. It was a small bright spot like a star, near the margin of the Moon, which he supposed at the time to be a hole or valley, which permitted the sun's light to shine through it. Succeeding observations have, however, led astronomers to believe, that appearances of this kind are occasioned by the

eruption of volcanic fire. Dr. Herschel, in particular, has observed several eruptions of this kind, the last of which he has described in the Philosophical Transactions for 1787, as follows: "On April the 19th, at 10h. 6m. I perceived three volcanoes in different places of the dark part of the new Moon. Two of them are either already nearly extinct, or otherwise in a state of going to break out, which perhaps may be decided next lunation. The third shows an actual eruption of fire or luminous matter: its light is much brighter than the nucleus of the Comet which M. Mechain discovered at Paris on the 10th of this month." The following night the Doctor found it burned with greater violence; and by measurement he found that the shining or burning matter must be more than three miles in diameter, of an irregular round figure, and very sharply defined about the edges. The other two volcanoes resembled large faint nebulæ, which appeared to be gradually brighter towards the middle, but no well defined luminous spot could be discovered in them. Dr. Herschel adds, "the appearance of what I have called the actual fire, or eruption of a volcano, exactly resembled a small piece of burning charcoal, when it is covered by a very thin coat of white ashes, which frequently adhere to it when it has been some time ignited; and it had a degree of brightness about as strong as that with which a coal would be seen to glow in fair daylight."

The appearance which Dr. Herschel here describes so minutely, was also observed at the Royal Observatory of Paris, about six days before, by Dominic Nouet, like a star of the sixth magnitude, the brightness of which occasionally increased by flashes. Other astronomers also saw the same thing, for M. de Villeneuve observed it on the 22d of May, 1787. This volcano is situated in the north-east part of the Moon, about 3′ from her edge, towards the spot called Helicon. After considering all the circumstances respecting these appearances which have just been mentioned, we must subscribe to Dr. Herschel's opinion, that volcanoes exist in the Moon as well as the earth.

It has long been a disputed point among astronomers, whether or not the Moon is surrounded by an atmosphere. Those who deny that she is, say that the Moon always appears with the same brightness when our atmosphere is clear; which could not be the case if she were surrounded by an atmosphere like ours, so variable in density, and so often obscured by clouds and vapours.

A second argument is, that when the Moon approaches a star, before she passes between it and the earth, the star neither alters its colour nor its situation, which would be the case if the Moon had an atmosphere, on account of the refraction, which would both alter the colour of the star, and also make it appear to change its place.

A third argument is, that as there are no seas or lakes in the Moon, there is, therefore, no atmosphere, as there is no water to be raised up into vapour. But those who contend that the Moon is surrounded by an atmosphere, deny that she always appears of the same brightness, even when our atmosphere appears equally clear. Instances of the contrary are mentioned by Hevelius and some other astronomers,

but it is unnecessary to take any farther notice of them here. In the case of total eclipses of the Moon, it is well known that she exhibits very different appearances, which it is supposed are owing to changes in the state of her atmosphere. It is remarked by Dr. Long, that Newton had shown that the weight of any body on the Moon, is but a third part of the weight of what the same body would be on the earth; from which he concludes that the atmosphere of the Moon is only one-third part as dense as that of the earth, and therefore it is impossible to produce any sensible refraction on the light of a fixed star which may pass through it. Other astronomers assert that they have observed such a refraction; and that Jupiter, Saturn, and the fixed stars had their circular figures changed into an elliptical one, on these occasions.

But although the moon be surrounded by an atmosphere of the same nature as that which surrounds the earth, and to extend as far from her surface; yet no such effect as a gradual diminution of the light of a fixed star could be occasioned by it, at least none, that could be observed by a spectator on the earth. For at the height of 44 miles our atmosphere is so rare, that it is incapable of refracting the rays of light, now this height is only the 180th part of the earth's diameter; but as clouds are never observed higher than 4 miles, it therefore follows that the obscure part of our atmosphere is about the 2000th part of the earth's diameter, and if the Moon's apparent diameter be divided by this number, it will give the angle under which the obscure part of her atmosphere will be seen from the earth, which is not quite one second, a space passed over by the Moon in less than two seconds of time. It can, therefore, scarcely be expected that any obscuration of a star could be observed in so short a time, although it do take place.

As to the argument against a lunar atmosphere, drawn from the conclusion, that there are no seas or lakes in the Moon, it proves nothing, because it is not positively known whether there is any *water* in the Moon or not.

The question of a lunar atmosphere seems to be at last settled by the numerous and accurate observations of the celebrated Astronomers Shroeter and Piazzi, who have proved as convincingly as the nature of the subject seems to allow, that the Moon has really an atmosphere, though much less dense than ours, and scarcely exceeding in height some of the lunar mountains.

It is remarked by Dr. Brewster, "The mountain scenery of the Moon bears a stronger resemblance to the lowering sublimity and terrific ruggedness of the Alpin regions, than to the tamer inequalities of less elevated countries. Huge masses of rock rise at once from the plains, and raise their peaked summits to an immense height in the air, while projecting craggs spring from their rugged flanks, and threatening the vallies below, seem to bid defiance to the laws of gravitation. Around the base of these frightful eminences, are strewed numerous loose and unconnected fragments, which time seems to have detached from their parent mass; and when we examine the rents and ravines which accompany the overhanging cliffs

we expect every moment that they are to be torn from their base, and that the process of destructive separation which we had only contemplated in its effects, is about to be exhibited before us in tremendous reality. The mountains called the Appennines, which traverse a portion of the Moon's disc from north-east to south-west, rise with a precipitous and craggy front from the level of the *Mare Imbrum*. In some places their perpendicular elevation is above four miles; and though they often descend to a much lower level, they present an inaccessible barrier to the north-east, while on the south-west they sink in gentle declivity to the plains."

The caverns which are observed on the Moon's surface, are no less remarkable than the rocks and mountains, some of them being three or four miles deep, and forty in diameter. A high angular ridge of rocks marked with lofty peaks and little cavities, generally encircles them, an insulated mountain frequently rises in their centre, and sometimes they contain smaller cavities of the same nature with themselves. These hollows are most numerous in the south-west part of the Moon, and it is from this cause that this part of the Moon is more brilliant than any other part of her disc. The mountainous ridges which encircle the cavities, reflect the greatest quantity of light; and from their lying in every possible direction, they appear, near the time of full Moon, like a number of brilliant radiations issuing from the small spot called Tycho.

It is difficult to explain, with any degree of probability, the formation of these immense cavities; it is highly probable, that the earth would assume the same figure, if all the seas and lakes were removed; and that the lunar cavities are either intended for the reception of water, or that they are the beds of lakes and seas which have formerly existed in the Moon.

The circumstance of there being no water in the Moon, affords a strong proof of the truth of this theory.

OF THE CONSTELLATIONS, OR ASTERISMS.

A spectator who observes the heavens with a tolerable degree of attention, will soon perceive, that by far the greater number of the stars never change their situation with respect to each other. Such stars as always appear to occupy the same situation in the heavens, or the same relative distance from one another, have been called *fixed stars*, to distinguish them from the *planets*, whose situations are constantly changing.* The fixed stars constitute by far the most numerous class of celestial bodies; for on casting the eye quickly to the heavens in a clear winter evening, they appear to be innumerable.

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* A planet may be known from a fixed star, by the steadiness of its light; for a fixed star appears to emit a twinkling light, but a planet gives a mild steady light.

The grandeur of such a scene, with the perpetual and regular change which the whole appears to undergo by the daily revolution of the earth on its axis, must have attracted the attention of mankind at a very early period. But previous to attempting to make either regular or accurate observations, on the motions and relative situations of the various bodies which compose this splendid scene, it was necessary to invent some method by which the one might be distinguished from the other. To give a particular *name* to every star which was visible to the naked eye, was impossible.

It therefore became necessary to adopt a more general method of distinguishing them. This was accomplished by portioning out the heavens into imaginary figures, of men, birds, fishes, &c. called Constellations or Asterisms. After this, the situation of a star could be known by mentioning its place in the Constellation in which it was situated; as the bull's eye, the lion's heart, the dog's nose, &c. In what age of the world this arrangement of the stars into constellations took place is not known, but it was certainly antecedent to any authentic record; so that whether the shepherd or the sage, was employed in their formation, cannot now be ascertained. Homer and Hesiod, who lived at least 800 years before the Christian era, mention several of the constellations.

> The Pleids, Hyads, with the northern team,
> And great Orion's more refulgent beam;
> To which, around the axle of the sky,
> The Bear revolving points his golden eye,
> Still shines exalted in th' ethereal plain,
> Nor bathes his blazing forehead in the main. POPE's *Homer*.

In the book of Job, Arcturus, Orion, and the Pleiades, are twice mentioned.

> Canst thou the sky's benevolence restrain,
> And cause the Pleiads to shine in vain?
> Or, when Orion sparkles from his sphere,
> Thaw the cold season, and unbind the year?
> Bid Mazzaroth his destin'd station know,
> And teach the bright Arcturus where to glow?

The writer of the book of Amos has also mentioned *Orion* and the *seven stars*; which plainly shews that the constellations must not only have been invented before his time, but that they must have been of some standing at that period.

These signs, which now seem so whimsical and uncouth, were not however the offspring of unsystematic fancy; they appear to have been intended to signify the state of the earth at the different seasons of the year, particularly the figures of the constellations in the Zodiac, which are supposed by some astronomers to be Egyptian hieroglyphics. Among these there are some that have as it were a common relation to every portion of the globe, while others seem to relate to circumstances or events merely local. *Aries*, is said to signify that the lambs begin to follow the sheep about the time of the

vernal equinox, when the sun enters this sign; and that the cows bring forth their young about the time he approaches the second constellation, Taurus, or the Bull. The third sign now called Gemini, was originally two *kids*, and signified the time of the goats bringing forth their young, which are usually two at a time, while the former (the sheep and the cow) commonly produce only one.

The fourth sign, Cancer the Crab, an animal that goes sideways and backwards, was placed at the northern *tropic*, or that point of the ecliptic, where the sun begins to return back again from the north to the southward. The fifth sign, Leo, the Lion, as being a furious animal, was thought to denote the heat and fury of the burning sun after he had left Cancer, and entered the next sign Leo.

The sixth sign received the sun at the time of the ripening of corn, and the approach of harvest; which was aptly expressed by one of the female reapers, with an ear of corn in her hand, namely Virgo, or the Virgin.

The next sign, Libra, or the Balance, evidently denotes the equality of days and nights, which take place at that season; and Scorpio, the next sign in order, denotes the time of gathering in the fruits of the earth, which being generally an unhealthly season, is represented by this venomous animal, extending his long claws, threatening the mischief which is to follow. The fall of the leaf was the season of the ancient hunting; and for this reason the constellation Sagittarius represents a huntsman with his arrows and his club; the weapons of destruction employed by huntsmen at that time. The reason of the Goat being chosen to mark the farthest south point of the ecliptic, is obvious enough, for when the sun has attained his extreme limit in that direction, he begins to return, and mounts again to the northward, which is very well represented by the goat, an animal that is always found climbing and ascending some mountain as it browses. As the winter has always been considered a wet and uncomfortable season, this was expressed by Aquarius, the figure of a man pouring out water from an urn. The last of the zodiacal constellations was Pisces, a couple of fishes tied together, which had been caught, which signified that the severe season was over, and though the flocks did not yet yield their store, yet the seas and rivers were open, and fish might be caught in abundance. These ideas have been beautifully expressed by Chatterton, in the following lines:

On the *earth's orbit* see the various signs,—
Mark where the sun our year completing, shines:
First the bright *Ram* his languid ray improves;
Next glaring wat'ry thro' the *Bull* he moves:
The am'rous *Twins* admit his genial ray;
Now burning, thro' the *Crab* he takes his way;
The *Lion*, flaming, bears the solar power;
The *Virgin* faints beneath the sultry shower.
Now the *just Balance* weighs his equal force,
The slimy *Serpent* swelters in his course;
The sable *Archer* clouds his languid face;
The *Goat* with tempests urges on his race;
Now in the *Water* his faint beams appear,
And the cold *Fishes* end the circling year.

Although these signs might have served to distinguish the seasons of the year when they were first formed, or employed for that purpose, yet this is not altogether the case at the present day. For owing to the retrograde motion of the equinoctial points, the constellations of the Zodiac have now so far changed their positions, as to be found more than a sign advanced.* The constellation Aries, for example, is now three or four degrees within the sign Taurus, or the first point of Aries, which used to coincide with the equinoctial point, is now about thirty-four degrees farther advanced; however, the first point of the *sign* Aries still continues to be reckoned from the equinoctial point. The signs of the Zodiac must therefore now be distinguished from the constellations, the signs merely being ideal, and serving only to designate the course of the sun in the ecliptic, while the constellations continue to signify a group or cluster of stars, designated by some particular name.

Besides the constellations in the Zodiac, the catalogue of Ptolomy, (which is the first or earliest on record) enumerate 21 to the north, and 15 to the south of it, making in all 48, but these included only the visible part of the heavens, or such as came under their notice. The number of constellations, however, increased, as the knowledge of the stars became more extensive; and at the same time more stars were introduced into each constellation, as their positions became known.

Such stars as were not included in any of these constellations, were called by the ancients informs or sporades stars; but modern astronomers have now reduced these *informs*, or unformed stars into new constellations, which have now swelled the number to 95. Of these 12 are in the zodiac, the names of which have already been mentioned; 37 to the north of it, and 46 to the south of it. The northern constellations are

Ursa Major	Corona Borealis	Aquila
Ursa Minor	Hercules	Antinöus
Draco	Cerberus	Delphinus
*Cepheus	Lyra	*Taurus Poniatowski
Andromeda	Cygnus	Equulus
Cassiopeia	*Vulpecula	Sagitta
Perseus	*Anser	Auriga
Pegasus	*Lacerta Stellio	*Lynx
*Canes Venatici	*Camelopardalus	*Leo Minor
*Böotes	Serpens	*Triangulum
*Mons Mænalus	*Serpentarius	Triangulum Minus
*Coma Berenices	Scutum Sobieski	*Musca.†
*Cor Caroli		

* See Precession of the Equinoxes, page 9.

† The new constellations are those marked thus (*).

The southern constellations are the following:—

Cetus
Eridanus
Phœnix
Toucan
Orion
Monoceras
Canis Major
Apus
Hydra
Sextans Uraniæ
Crater
Corvus
Centaurus
Lupus
Ara
*Triangulum Australe
*Pavo
Corona Australis
*Grus
Piscis Australis
*Lepus
*Columba Noachi
*Robur Caroli
*Crux
Argo Navis
Canis Minor
*Apis Musca
Hirundo
*Indus
*Telescopium
*Microscopium
*Octans Hadleianus
*Cameleon
*Piscis Volans
*Xiphias
*Officina Sculptoris
*Hydrus
*Fornax Chemica
*Horologium
*Reticulus Rhomboidalis
*Praxiteles
*Equuleus Pictorius
*Pyxis Nautica
*Machina Pneumatica
*Circinus
*Quadra Euclidis.†

Though the division of the heavens into the constellations above enumerated, be entirely fanciful, yet it is of great advantage in describing the position of particular stars. The judicious and practical astronomer has therefore always resisted every attempt, either to change their names, or to lay them aside, because better could not be substituted in their place; and because they keep up the greater correspondence and uniformity between the old astronomy and the new.

ON THE POSITION OF THE CONSTELLATIONS, AND PRINCIPAL STARS IN THE NORTHERN HEMISPHERE.

As there is no particular constellation, or star, in the heavens, so singular in its appearance, or so singularly situated with respect to the rest, as to entitle it to the distinction of being first described, but as the constellation Ursa Major, or the Great Bear, never goes below the horizon of places of considerable northern latitude; and as it is one of the most conspicuous constellations in the northern hemisphere, we shall not only begin to describe it first, but endeavour to trace out the others by means of it.

In the Great Bear there are seven very conspicuous stars, four of which form a trapezium in the body, and the other three are in the tail of that animal. The two former stars in the trapezium are called the *guards*, or pointers, because a straight line passing through them points out the pole. The pointer which is nearest the pole star is called *Dubhe*; the first in the tail next the body, *Alioth*; and the last in the tail, *Benetnach*.‡

Nearly in the direction of the pointers, and about five times the interval between them, reckoning from Dubhe, is Alruccabah, or the Pole Star, situated in the tip of the tail of the constellation Uursa Minor, in which there are also seven stars, forming a figure

† The new constellations are those marked thus (*).

‡ These seven stars form a figure somewhat resembling a plough; hence it is often called Charles' Wain, or the Plough.

like those in the Great Bear, but both the figure and the stars are considerably less.

> The Lesser Bear
> Leads from the pole the lucid band: the stars
> Which from this constellation, faintly shine
> Twice twelve in number; only one beams forth
> Conspicuous in high splendor, nam'd by Greece
> The CYNOSURE; by us the POLAR STAR. EUDOSIA.

An imaginary line passing from Dubhe through the star in the opposite corner of the trapezium, will nearly intersect Cor Caroli, a single star of the second magnitude, whose distance from the latter star is nearly double that between the two former. A straight line from Alioth passing through Cor Caroli, produced a little farther than the distance between them, will reach Vindemiatrix, the farthest northern star in the constellation Virgo. Between Cor Caroli and Virgo is the constellation Coma Berenices, or Berenice's Hair, so named from its resemblance to hair.

> Then Berenice's locks first rose so bright,
> The heavens bespangling with dishevelled light. POPE.

A straight line from Benetnach passing through Cor Caroli, and extending downwards or towards the horizon about double the distance between these two stars, will reach Deneb, a star of the second magnitude in the constellation Leo, or the Lion, and about 25 degrees to the west of Deneb; and about 3 degrees lower is Regulus, a star of the first magnitude, in the heart of Leo, and almost in the plane of the ecliptic.

To the eastward of Deneb, at the distance of about 35 degrees, is Arcturus, in the constellation Böotes, called the Waggoner.

> Wide o'er the spacious regions of the North,
> Böotes urges on his tardy wain. THOMSON.

> Böotes with his wain the North unfolds;
> The southern gate Orion holds. CLAUDIAN.

Under Böotes is the constellation Virgo, in which there is a very bright star, called Spica Virginis, which forms with Deneb and Arcturus a very large equilateral triangle.

A little to the south-west of Spica Virginis, is the constellation Corvus, the stars of which form a long trapezium, but none of them exceed the third magnitude. The first star is named Algorab, and is in the lower corner of the trapezium, about 18 degrees from Spica Virginis.

A line from Vindemiatrix, the third star in Virgo, through Arcturus, will intersect Alphacca, a star of the second magnitude in the constellation Corona Borealis, or the Northern Crown; the distance between Alphacca and Arcturus being nearly equal to that between the latter and Vindemiatrix. This constellation is very conspicuous, the stars in it being arranged in a circular form, somewhat resembling a crown. A line passing from Regulus through Spica Virginis, and extending an equal distance beyond the latter will

reach Antares, a star of the first magnitude in the constellation Scorpio. Between Scorpio and Virgo is the constellation Libra, containing a number of small stars; and to the south of Scorpio is the constellation Lupus, or the Wolf, which also contains a number of stars; but none of them exceed the third or fourth magnitude.

Nearly in the line produced from Arcturus, through the Northern Crown, and about twice the distance between them, and beyond Alphacca, is one of the brightest stars in the heavens, called Vega, in the constellation Lyra. In the line joining this star and the guards of Ursa Minor, and about 15 degrees distant from the former, is Rastaban, a star of the third magnitude in the constellation Draco, or the Dragon; and in the opposite direction from Vega, a little to the east of the line, and about 34 degrees distant, is Altair, a star between the first and second magnitude in the constellation Aquila. The stars Altair, Vega, and Deneb, a star of the second magnitude in the constellation Cygnus, form nearly a right-angled triangle, the right angle being at Vega. About 14 degrees north-east of Altair, is a romboidal figure, formed by four stars in the constellation Delphinus; and about 35 or 36 degrees east of this figure, is the constellation Pegasus, in which there is a bright star in the neck called Scheat. About 13 degrees south of that is Markab, a star of the second magnitude; 16 degrees to the east of Markab is another star of the second magnitude, in the same constellation; and nearly 14 degrees east of Scheat is a star of the third magnitude, in the head Andromeda. These four stars form a square, usually called the Square of Pegasus.

A line from Scheat through Markab, at the distance of 45 degrees from the latter, will nearly intersect Fomalhaut, a star of the first magnitude in the constellation Pisces Austraulis, or the Southern Fish. Between Markab and Fomalhaut, and about 10 degrees south of the former, is the constellation Pisces. To the west of the line joining the two last mentioned constellations is Aquarius, one of the zodiacal constellations.

A line from Deneb in Cygnus, passing through Markab, and distant from it about 41 degrees, will point out the second brightest star in the constellation Cetus: and a line from the rhomboid already mentioned, in Delphenus, through Markab, at the distance of nearly 60 degrees from this last star, will intersect Menkar, a star of the second magnitude in the jaw of Cetus. About 37 degrees north of Menkar is Algol, the second star in the constellation Perseus, which is one of those stars that vary in brightness.

At the distance of about 27 degrees from the star in the head of Andromeda, and a little to the south of the line, joining it and Markab, is Almaach, a star of the second magnitude in the southern foot of Andromeda: and about half way between it and Markab, is Mirach, a star of the third magnitude in the girdle of that constellation. A little to the north of the same line, at the distance of about 42 degrees, is Algenib, a star of the second magnitude in the constellation Perseus. The three stars, Almaach, Algol, and Algenib, form nearly a right-angled triangle, Algol being at the right angle.

Between Mirach and Menkar, about 17 degrees from the former, is a tolerably bright star of the second magnitude in the constellation Aries, between which and Almaach are the two triangles, and about 10 degrees south-east of the triangles is the small constellation Musca, or the Fly. To the north-east of Menkar, about 26 degrees, and as many south-east of Musca, is Aldebaran, a star of the first magnitude, of a red colour, in the constellation Taurus. This star, with several other small ones called the Hyades, forms a triangle. Between this triangle and Musca, is that well-known cluster of stars called the Pleiades, or Seven Stars, which are situated in the neck of Taurus. A line from Aldebaran through Algol, at the distance of 28 degrees from Algol, will intersect Schedar, a star of the third magnitude in the constellation Cassiopeia. This constellation will easily be known, being composed of five or six stars of nearly the same magnitude, and being always on the opposite side of the pole, with respect to the star Alioth, in Ursa Major.

About 22 degrees south-east from Aldebaran, are three stars of the second magnitude, in a straight line, and at equal distances from each other, which form the belt of Orion. Below the belt are a few stars that compose the Sword of Orion, in a beautiful nebulæ. Above these are two bright stars, distant from each other about $7\frac{1}{2}$ degrees; the farthest west one is called Bellatrix, and the other Betelguese; and, about as far distant on the other side of the belt is Rigel, a star of the first magnitude; all of these are in the constellation Orion, which is one of the most beautiful constellations in the heavens. About half way between Rigel and the north pole is Capella, a star of the first magnitude in the constellation Auriga. A line from Menkar through Rigel, at the distance of $23\frac{1}{2}$ degrees from the latter, or from Aldebaran, through the middle star of Orion's belt, and about as far below it as Aldebaran is above it, is Sirius, a star of the first magnitude in the constellation Canis Major.* About $5\frac{1}{2}$ degrees west from Sirius is a star between the second and third magnitude, and about 11 degrees farther south than Sirius there are three others in a straight line, all of the third magnitude, and in the same constellation. About 26 degrees to the east of Betelguese, and the same distance north-east from Sirius, is Procyon, a star between the first and second magnitude in Canis Minor. In a line with Rigel and the middle star in the belt of Orion, about 44 degrees from the latter, is Castor, a star between the first and second magnitude, in the constellation Gemini; and about $4\frac{1}{2}$ degrees south-east of Castor is Pollux, a star between the second and third magnitude, in the same constellation. Pollux may also be known by observing that it is about 45 degrees distant from Aldebaran, in the line produced, passing through it from Menkar. About half way between Procyon and Regulus is Acubens, a star of the third magnitude in the sign Cancer. A line from Alioth through Regulus being produced about 23 degrees, will intersect Alphared, a star of the second

* Sirius is the brightest star in the heavens, and is by some astronomers supposed to be nearest the earth.

magnitude in the constellation Hydra; and a line from Procyon through Alphared, produced about 24½ degrees beyond Alphared, will intersect Alkes in the constellation Crater. This star may also be known by being on the meridian nearly at the same time with the pointers in the Great Bear.

As the constellations and stars now described comprise the greater number of those that can be seen in any part of Great Britain, it is unnecessary to take any notice of the others.*

The situation of the principal constellations which appear above the horizon of London, during a night about the middle of December, are so beautifully and accurately described in the following extract from the philosophic poem entitled Eudosia, that it cannot but be admired by all lovers of Astronomy:—

Now let us watch the rising of the stars;
And look where mid December points the hour
Most apt for contemplation of the scene.
The fourth from noon is pass'd, and half the space
Fled to the fifth; in the meridian view
Cepheus, sublime; the Dragon's tortile spire,
Where shines to Britain's great metropolis,
The correspondent star; alike remote
This from the heavenly, that the earthly pole,
And perfectly coincident in place,
The greater Bear is seen; and Pegasus
Tends to the south; the beauteous Twins emerge
from the horizon; Taurus climbs oblique;
Still higher Aries; the declining Fish
Verge to the southern wave; and Capricorn
Glistens, diminish'd, in the western sky:
And, near the goal, with languid ray appears
Chiron; but, nigh to the direct of east,
Orion half is risen; nor prevails
The horizon even now to eclipse the pomp
Of the proud constellation; his right side
Blazes; the star, which lightens on the left,
Is winning now upon our hemisphere:
And near him the vast Whale conspicuous shines.
The sixth hour is elaps'd, Orion shows
His flaming belt; the Twins are wholly risen!
Soon Procyon appears! and now the Crown
Of Ariadne rises: Charles, thy star,
Though never setting to the horizon, stoops.
And of the Crab the far distinguish'd light
Emerges. Little later than the seventh,
Sirius appears: the ninth the Lion shines;
And in the vertex is Medusa seen.
Near the tenth hour from noon Hydra appears
Southward; at mid of night Orion's form
Fires the meridian; but the Whale retired;
The radiant Lyra meets the horizons' bound;
The Virgin form shows her ascendant wing;

* Those who are possessed of a celestial globe, and know how to use it, will, in a few evenings, acquire a knowledge of the principal stars that may be above their horizon at that season; but the foregoing directions will be found to answer the same purpose, with the assistance either of a globe or map of the heavens.

Capella in the zenith glows; an hour
Is pass'd; Arcturus rises: ere the night
Has mark'd the second hour from its mid space,
Shoots in full beam the great NEWTONIAN *Star.**
The fourth approaches, when the golden star
Of Libra gains the eye: the sails retire
Of the resplendent Ship; her lucid mast
Shines eminent. The sixth her fetter'd arm
Andromeda discovers; and the heart
Of Scorpio rises; Hydra fills the west;
Medusa's Head sinks, and Orion bears
With difficulty his shoulders unsubmerg'd:
Monocerous succeeds. Why should I name
The Snake or Serpentarius fully risen?
Or why repeat the wonders which before
Engag'd our eye? The great and smaller Bear,
With the Camelopard and varied Lynx!
Or gaze on thee, O Perseus! thee admire,
Aquila; or the Lyre, which re-ascends?
But, rising eastward, beams the glorious arch
Of the pure Galaxy? And now appears
Urania's Sextant, and persuades to leave
The starry theatre, and yield to dawn:
For now Aurora's fiery coursers gild
The frosty summit of the eastern hills.
All this delightful scene revolving earth
Produces, visiting the several stars;
While undisturb'd remain the heavenly spheres. EUDOSIA.

OF THE LUSTRE AND MAGNITUDE OF THE STARS.

One sun by day, by night *ten thousand* shine;
And light us deep into the DEITY.
O how loud
They call devotion, genuine growth of *night!*
Devotion, daughter of Astronomy!
An undevout astronomer is mad. YOUNG.

The stars are divided into orders or classes according to their apparent magnitudes. Those that appear largest to the naked eye, have been called stars of the first magnitude; those that appear next largest, the second magnitude; and so on to the sixth, which comprehends the smallest stars that are visible to the naked eye. All those that can only be perceived by the help of a telescope, are called telescopic stars.

The stars of each class are not all of the *same* apparent magnitude. In the first class, or those of the first magnitude, there are scarcely two that appear of the same size.

There are also other stars, of intermediate magnitudes, which astronomers cannot refer to any particular class, and therefore they place them between two; but on this subject astronomers differ con-

* Spica Virginus, the ear of wheat in the constellation Virgo:—
——The star which crowns the golden sheaf,
And wants a name, O glory of the skies!
And shall not justice dignify thy sphere
With the great name of NEWTON? Be at least
To me for ever the *Newtonian Star.* EUDOSIA

siderably; some of them classing a star among those of the first magnitude, while others class it among those of the second, and so on with others.

In fact it may be said, that there are almost as many orders of stars as there are stars, on account of the great variations observable in their magnitude, colour, brightness, &c. Whether these varieties of appearance are owing to a diversity in their *real* magnitude, or from their different distances, is impossible to determine; but it is highly probable that both of these causes contribute to produce these effects.

To the naked eye, the stars appear of a sensible magnitude, owing to the glare of light arising from the numberless reflections from the aërial particles, &c. about the eye; this makes us imagine the stars to be much larger than they would appear, if we saw them only by the few rays which come directly from them, so as to enter our eyes without being intermixed with others. Any person may be sensible of this by looking at a star of the first magnitude through a long narrow tube, which, though it takes in as much of the heavens as would hold a thousand such stars, scarcely renders that one visible. The stars being so immensely distant from the earth, there seems to be but little probability of ascertaining with certainty the real magnitude of any of them. And as Dr. Herschel has very justly remarked, "that, in the classification of stars into magnitudes, there is either no natural standard, or at least none that can be satisfactory; and that the astronomers who have thus classed them, have referred their size or lustre to some imaginary standard."

The same illustrious astronomer observes, "that the inconvenience arising from this unknown, or at least ill-ascertained, standard, to which we are to refer, is such, that now our most careful observations labour under the greatest disadvantage. If any dependence could be placed on the method of magnitudes, it would follow, that many of the stars had undergone a change in their lustre or apparent magnitude, even since the time of Dr. Flamstead.—Not less than eleven stars, in the constellation Leo, have undergone a change of lustre since his time." This change, Dr. Herschel believes, has arisen from the uncertainty of the standard of magnitudes, and not from any real change in the lustre of the stars: and in order to prevent mistakes of this nature to future observers, the Doctor proposes to compare the lustre of any particular star with that of one which is greater, and also one that is less, both of which to be as near the proposed star as possible. This he thinks would answer much better for detecting a change in the lustre of any suspected star than the vague method of magnitudes, which has been hitherto in use among astronomers.

As a full display of the Doctor's method would occupy more space than can be allotted to it in this work, those who wish to have more information on the subject, may consult the Phil. Trans. vol. 86.

That many real changes in the lustre of stars have taken place, Dr. Herschel acknowledges; for he says, "If we consider how

little attention has been paid to this subject, and that most of the observations which we have are of a very late date, it will perhaps not appear extraordinary were we to admit the number of alterations that have probably happened to different stars to be 100; this, compared with the number of stars that have been examined, with a view to ascertain their changes, which we can hardly rate at 3000, will give us a proportion of 1 to 30. But we are certain, that had a number of observers applied themselves to the same subject, many more discoveries might probably have been made of changeable and periodical stars, whose variations are too small to strike a general observer. By observations of this nature," continues this celebrated astronomer, "we are enabled to resolve a problem, not only of great importance in itself, but one in which we are all immediately concerned. Who, for instance, would not wish to know what degree of permanency we ought to ascribe to the lustre of our sun? Not only the stability of our climates, but the very existence of the whole animal and vegetable creation, are involved in the question. Where can we hope to receive information on this subject, but from astronomical observations? If the similarity of the stars to our sun be admitted, how necessary does it become to observe the fate of neighbouring suns, in order to guess at that of our own! That star among the multitude which we have dignified with the name of sun, to-morrow may slowly begin to undergo a gradual decay of brightness, like β in Leo, α in Cetus, α in Draco, δ in Ursa Major, and many others. It may suddenly increase, like the wonderful star in the back of Cassiopeia's Chair, and the no less remarkable one in the foot of the Serpent; a gradual increase, like ζ in Gemini, β in Cetus, and many other stars which have been known to increase in lustre. And lastly, it may turn into a periodical one of 25 days, as Algol is of 3 days, δ in Cepheus of 5, β in Lyre of 6, or as many others are of various periods."*

"If by proper attention to this subject," continues the Doctor, "it should be found that all, or many of the stars which we now have reason to suspect to be changeable, are really subject to an alteration in their lustre, it will much lessen the confidence we have hitherto placed on the permanency of the equal emission of light by our sun. Many phenomena in natural history seem to point out some past changes in our climates. Perhaps the easiest way of accounting for them may be to surmise that our sun has been formerly sometimes more and sometimes less bright than it is at present: and that many of the unaccountable varieties which happen in our seasons, such as a general severity or mildness of uncommon winters, or burning

* The stars in each constellation are marked or distinguished by the letters of the Greek alphabet; and some remarkable ones have particular names, as Aldebaran, Sirius, Algol, &c. The brightest star in each constellation is marked with the first letter, the next brightest with the second letter, and so on; but if there should be a greater number of stars in any constellation, than there are letters in the Greek alphabet, the Roman alphabet is then employed, and afterwards the italic.

summers, may possibly meet with an easy solution in the real inequality of the sun's rays."

Various hypotheses have been devised to account for the changes and appearances of the stars. Some astronomers have supposed that the periodical stars have vast dark spots, or dark sides, and very slow rotations on their axes, by which means they must disappear when the dark side is turned to the earth. Others are of opinion that the luminous surfaces of these bodies is subject to perpetual change, which sometimes increases their light, and at others extinguishes it.

Some have also ascribed the variation in the light of the stars, to the intesposition of the planets that revolve round them; but it is not very probable that these planets are sufficiently large to produce such an effect. Several other hypotheses might be mentioned, which have been advanced at different periods to account for these extraordinary changes; but as they rest upon mere conjecture, and are still more improbable than any of those just mentioned, it is unnecessary to give any account of them.

OF THE NUMBER OF THE STARS.

Why from yon arch, that infinite of space,
With infinite of lucid orbs replete,
Which set the living firmament on fire,
At the first glance, in such an overwhelm
Of wonderful, on man's astonished sight
Rushes Omnipotence?

The number of the stars appears to be uncommonly great on first casting the eye to the heavens in a very clear winter evening; but astronomers have long ago ascertained, that the number of such as are visible to the naked eye in both hemispheres, does not amount to 2000. This may at first appear incredible to some, because at first sight they seem to be innumerable; but the deception arises from looking upon them hastily, without reducing them into any kind of order. For let any person look steadily for some time upon a large portion of the heavens, and count the number of stars in it, and he will be surprised to find the number so small. And if the moon be observed for a short space of time, she will be found to pass very few in her way, although there are as many about her path as in any other part of the heavens. Flamstead's Catalogue contains only 3000 stars, and many of these are not visible without a telescope.

But although the number may be small when examined with the naked eye, yet when examined with a powerful telescope the number exceeds all computation. For a good telescope directed to almost any part of the heavens, discovers multitudes that are lost to the naked eye. In some places, however, they are crowded together; and in others there are considerable spaces where no stars can be seen. In the small group called the Pleiades, in which 6 or 7 stars

can only be seen by the naked eye, Dr. Hook discovered 78 stars with a telescope, and F. de Rheita 188. The same astronomer affirms, that he has observed above 2000 stars in the single constellation Orion. And Huygens, when looking at the star in the middle of Orion's sword, instead of one, found that there were 12. Galileo found 80 in the space of the belt of Orion's sword, 21 in the nebulous star in his head, and above 500 in another part of him, within the compass of one or two degrees space, and more than 40 in the nebulous star Præsepe.

There are also many stars which have the appearance of being single to the naked eye, but when examined with a good telescope, are found to be double, treble, &c. Of those, several have been observed by Cassini, Hook, Long, Maskelyne, and some other astronomers; but Dr. Herschel has been the most successful observer of these remarkable objects. He has already given a catalogue of above 700 double stars, most of which have never been noticed before by any other person. Among these there are also some stars that are treble, double-double or quadruple, double-treble, and multiple.*

So late descried by Herschel's piercing sight,
Hang the bright squadrons of the twinkling night
Ten thousand marshall'd stars, or silver zone,
Effuse their blended lustres round her throne,
Suns call to suns, in lucid clouds conspire,
And light exterior skies with golden fire.
Resistless rolls th' illimitable sphere,
And one great circle forms the unmeasured year

Besides those starry groups, where the individual stars are distinctly visible, there are numbers of small luminous spots, of a cloudy appearance, called Nebulæ. Of these a few have been noticed by the ancients; but since the invention of the telescope, many more have been discovered, particularly by Dr. Herschel, who has given a catalogue of 2500 nebulæ. The largest of these nebulæ is the Galaxy, or Milky Way, a broad, irregular, luminous zone, which nearly encircles the heavens, and appears to be the nearest of all the nebulæ.

Nor need we with a prying eye survey
The distant skies to find the Milky-Way:
It forcibly obtrudes upon our sight. CREECH.

From the observations of Dr. Herschel, it appears that this extensive portion of the heavens is completely crowded with stars; for he says, "On applying the telescope to a part of the Via Lactea, (that

* This catalogue is contained in the 72d and 75th Vol. of the Transactions of the Royal Society.

is, the Milky Way) I found that it completely resolved the whole whitish appearance into small stars, which my former telescope had not light enough to effect.*

> A way there is in heaven's extended plain,
> Which when the skies are clear is seen below,
> And mortals, by the name of Milky, know:
> The ground-work is of stars; through which the road
> Lies open to great Jupiter's abode. DRYDEN from OVID.

The portion of this extensive tract which it has hitherto been convenient for me to observe, is that immediately about the hand and club of Orion. The glorious multitude of stars of all possible sizes that presented themselves here to my view, was truly astonishing; but as the dazzling brightness of glittering stars may easily mislead us so far as to estimate their number greater than it really is, I endeavoured to ascertain this point, by counting many fields, and computing from a mean of them, what a certain given proportion of the Milky Way might contain. Among many trials of this sort, I found that six fields, promiscuously taken, contained 110, 60, 70, 90, and 74 stars each. I then tried to pick out the most vacant place that was to be found in that neighbourhood, and counted 63 stars. A mean of the first 6 gives 79 stars for each field. Hence, by allowing 15 minutes of a great circle for the diameter of any field of view, we gather, that a field of 15 degrees long, and 2 broad, or the quantity which I have often seen pass through the field of my telescope in one hour's time, could not well contain less than 50,000 stars that were large enough to be distinctly numbered. But, besides these, I suspected at least twice as many more, which, for want of light, I could only see now and then, by faint glittering and interrupted glimpses."

The Doctor goes on to make some remarks on nebulæ and clusters of stars in general, and then observes, "That they are generally arranged in strata, which seems to run on to a great length, some of which I was able to pursue, so as to guess pretty well their form and direction. It is probable enough that they may surround the whole apparent sphere of the heavens not unlike the Milky Way, which undoubtedly is nothing but a stratum of fixed stars. And as this latter immense starry bed is not of equal breadth or lustre in every part, nor runs on in one straight direction, but is curved and even divided into two streams along a very considerable portion of it, we may likewise expect the greatest variety in the strata of other clusters of stars and nebulæ. One of these nebulous beds is so rich, that in passing through a section of it, in the time of 36 minutes, I detected no less than 31 nebulæ, all distinctly visible on a fine blue sky. Their situation and shape, as well as condition,

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* The telescope here alluded to was a reflector of 20 feet focal distance, and its aperture $16\frac{7}{10}$ inches.

seems to denote the greatest variety imaginable. In another stratum, or perhaps a different branch of the former, I have seen double and treble nebulæ variously arranged; large ones with small, seeming attendants; narrow but much extended, lucid nebulæ or bright dashes; some of the shape of a fan, resembling an electric brush, issuing from a lucid point; others of a cometic shape, with a seeming nucleus in the centre; or like cloudy stars, surrounded with a nebulous atmosphere; a different sort again contain a nebulosity of the milky kind; while others shine with a fainter, mottled kind of light, which denotes their being resolvable into stars."

These observations serve to prove the intimate connection between the nebulous and sidereal condition; and, although in passing from the one to the other, a number of ambiguous objects are to be met with, yet this apparent uncertainty in the construction is only the consequence of the want of an adequate power in our telescopes to shew them of their real form. There is, however, no reason to expect that an increase of light and distinctness in our telescopes would free us altogether from ambiguous objects; for by improving our power of penetrating into space, and of defining those which at present appear indistinct, we should probably reach so many new objects, that others, of an equally obscure construction, would obtrude themselves, even in greater number, on account of the increased space of the more distant regions in which they were situated.

Dr. Herschel is of opinion that there is some operation going on in the heavens, by which new sidereal bodies are gradually and progressively formed or drawn into clusters or nebulæ; and that these clusters in time become more compressed or condensed, and ultimately assume a globular form. The power by which these extraordinary operations are performed, Dr. H. calls the *clustering power*. And he thinks that in time this power will have the effect of completely breaking up the Milky Way, and of converting it into globular insulated clusters. For he says, "Since the stars of the Milky Way are permanently exposed to the action of a power whereby they are irresistibly drawn into groups, we may be certain that from mere clustering stars they will be gradually compressed through successive stages of accumulation, till they come up to what may be called the ripening period of the globular form, and total insulation; from which it is evident that the Milky Way must be finally broken up, and cease to be a stratum of scattered stars."

"From this gradual dissolution of the Milky Way," continues the Doctor, "we may draw a very important conclusion; for the state into which the incessant action of the clustering power has brought it at present, is a kind of chronometer, that may be used to measure the time of its past and future existence; and although we do not know the rate of going of this mysterious chronometer, it is nevertheless certain, that, since the breaking up of various parts of the Milky Way affords a proof that it cannot last for ever, it equally

bears witness that its past duration cannot be admitted to be infinite.*

If we reflect for a moment on the amazing number of stars which the Milky Way contains, and grant that all the other nebulæ which the powerful telescopes of Dr. Herschel have enabled him to discover, are composed of distinct individual stars, then may we exclaim with the Psalmist,

"The heavens declare the glory of God, and the firmament sheweth his handy work."

OF THE DISTANCE OF THE STARS.

How distant some of the nocturnal suns!
So distant says the sage, 'twere not absurd
To doubt, if beams set out at Nature's birth,
Are yet arrived at this so foreign world;
Though nothing half so rapid as their flight.
An eye of awe and wonder let me roll,
And roll for ever. Who can satiate sight
In such a scene, in such an ocean wide
Of deep astonishment? Where depth, heighth, breadth,
Are lost in their extremes; and where to count
The thick-sown glories in this field of fire,
Perhaps a seraph's computation fails. YOUNG.

To find the distance of the fixed stars is a problem which many eminent astronomers have attempted to solve; but notwithstanding all their skill and exertions, this desirable object has never been satisfactorily accomplished. Various methods have been pursued without success; and the result of the finest observations has scarcely given us more than a distant approximation. For trigonometry, by whose powerful assistance the mathematician has boldly ascended to the planetary regions, and measured the diameters and orbits of the various bodies which compose the solar system, for want of a proper base, is here but of little service; for the whole diameter of the earth's orbit, which is nearly 190 millions of miles, is a mere point when compared with the immense distance of the fixed stars. Now as this base cannot be enlarged, the only chance that remains of solving the problem mathematically, is to endeavour to improve the instruments which are employed in measuring their parallax; for unless this is accurately ascertained, it is impossible to find their real distance.† But the accuracy and nicety of the instruments which have already been employed by the most skilful and assiduous astronomers, in attempts to find the parallax of some of the stars, leave us little hope of this important discovery ever

* In Bode's Atlas Cœlestis, 157 clusters are given as existing in the Milky Way, to which Dr. Herschel says 68 more must be added, which are to be found in the less rich parts of that surprising region of the heavens.

† See an explanation of this term at page 9.

being made. Dr. Bradley assures us, that had the parallax of γ Draconis amounted to a single second, he must have perceived it in the great number of observations he made upon it; and that it seemed to him, that the annual parallax of this star does not amount to a single second, and consequently that it is above 400,000 times farther from us than the sun, or 38,000,000,000,000 miles.* But as this is only a bright star of the *third* magnitude, "it is probable," says Dr. Herschel, "that its parallax is much less than that of a star of the *first* magnitude."

Allowing this to be the case, and supposing the parallax of a star to amount to *one second*, its distance cannot be less than 103,130 times the breadth of the earth's orbit, or 19,594,700,000,000 miles. As these distances are so immensely great, it may amuse as well as assist the mind, in forming a more correct idea of their vastness, to compare them with the velocity of some moving body which may be measured.

The swiftest motion of which we have any knowledge, is that of light, which passes from the sun to the earth, or 95 million of miles in 8 minutes 13 seconds, would require more than 6 years to pass over the former of the above distances, or to arrive at the earth from γ Draconis: and above 3 years to pass over the latter, or from one of the nearest of the fixed stars. But a cannon-ball, though continuing to move at the rate of 20 miles per minute, would be 3 millions 8 hundred thousand years in passing from γ Draconis to the earth, and 1 million 960 thousand years in passing from the nearest fixed star. Sound, which moves at the rate of about 13 miles in a minute, would be 5 million 600 thousand years in traversing the former distance, and 2 million 800 thousand, in passing through the latter.

The celebrated astronomer, Huygens, pursued speculations of this kind so far, as to believe it not impossible that there may be stars at such inconceivable distances, that their light has not yet reached the earth since their creation.

The late Professor Playfair, in speaking of the fixed stars, says, "As it cannot be doubted that the fixed stars are luminous bodies like the sun, it is probable that they are not nearer to one another than the sun is to the nearest of them. When, therefore, two stars appear like a double star, or very near to one another, the one must be placed far behind the other, but nearly in the same straight line when seen from the earth. The same must hold, at least in a certain degree, wherever a great number of stars are seen concentrated in a small spot. In the starry Nebulæ, such as the Milky Way, which derive their light from the number of small stars, appearing as if in contact with each other, it is plain that the most distant of these must be many thousand times farther off than the nearest, and light must of course require many thousand years to come from them to

* Various methods have been proposed and repeatedly attempted, in order to discover the parallax of the stars, by many celebrated astronomers, without success; but this is a subject which does not belong to a work like the present.

the earth. The poet has been taxed with exaggeration who spoke of

> Fields of radiance, whose unfading light
> Has travelled the profound six thousand years,
> Nor yet arrived in sight of mortal things.

Yet the fields which he describes are far within the circle to which the observations of the astronomer extend."

Dr. Halley has also advanced what, he says, seems to be a metaphysical paradox; namely, that the number of the fixed stars must be more than *finate*, and some of them at more than finate distances from us; and Addison has justly observed, "That this thought is far from being extravagant, when we consider that the universe is the work of infinite power, prompted by infinite goodness, and having an infinite space to exert itself in, so that our imagination can set no bounds to it."

OF THE NATURE OF THE FIXED STARS.

> Ten thousand suns appear,
> Of elder beam; which ask no leave to shine
> Of our terrestrial star, nor borrow light
> From the proud regent of our scanty day.
>
> BARBAULD.

The immense distance of the fixed stars leaves us but little hope of ever being able to determine their nature with complete certainty. By analogical reasoning, and a careful attention to the various phenomena which they present, we may make approaches to this interesting and important discovery.

From the fruitless attempts which have often been made to determine their annual parallax, it is fully ascertained that they are many thousand times farther distant from us, than the most remote planet which belongs to the solar system; and yet some of them shine with a degree of brilliancy, which even rivals that of Venus or Jupiter. Hence it is evident they cannot derive their light from the same source as these planets do, viz. from the sun; and if they derived their light from any other luminous body which was nearer them, that body would certainly be visible to us, as well as those to which it communicated the light which rendered them visible. But as we know of no other luminous body beside the sun from which they could derive their light, it follows that they shine with their own native light. One powerful argument in support of this opinion is, that the stars appear to be much less when examined with a powerful telescope, than they do to the naked eye; for they appear to be mere luminous points when viewed through a telescope, which magnifies three or four hundred times. Now, if they shone by a borrowed light, they would be as invisible to the naked eye as the satellites of Jupiter or Saturn. But though these satellites be invisible to the naked eye, yet, when viewed through a telescope of a tolerable

magnifying power, they are not only seen distinctly, but they appear to be much larger than any of the fixed stars. Hence it is inferred that the fixed stars shine by their own proper light; and when their immense distances are taken into account, we cannot hesitate to admit that their real magnitude considerably exceeds that of any of the planets. The fixed stars, then, seem to be of a nature very similar to the sun; and that they are suns in reality scarcely admits of a doubt; for the analogy between them may be traced in many particulars. The sun turns on his axis; so do many of the fixed stars, and most probably all.* The sun has spots on his surface; so has the star *Algol* and some others, and probably all the stars of the heavens. On the sun these spots are changeable; so they are on several of the stars, as Dr. Herschel and some other astronomers have repeatedly observed. If, then, the fixed stars resemble the sun in so many particulars, is it not highly probable that each of them is designed to answer similar purposes? Is it not reasonable to conceive that each star is the centre of a system, and has planets revolving round it. which are illuminated, warmed, and cherished by its light and heat.

We certainly cannot imagine that the fixed stars were formed for no other purpose than to cast a faint light upon the earth, especially when we consider that we have incomparably more light from the moon than from all the stars put together, and that innumerable stars, so far from giving us light, are not even discernable, without the aid of the most powerful telescopes.

If our sun, with the whole system of planets, moons, and comets, were to be removed to the distance of the nearest fixed star, not one of them would be visible except the sun, which would then appear, not with the brilliancy and lustre which he does at present, but like a star of the first or second magnitude. Instead, therefore, of looking upon the fixed stars as a curious species of twinkling flames hung up in the spacious canopy of heaven, merely to ornament it, or to add to the delight of man, let us suffer our conceptions to expand till they embrace a wider field of contemplation: but in doing this let us also keep within the bounds of probability, which the true astronomer on no occasion goes beyond.

When the immense distance of the fixed stars is taken into consideration, we shall not be accused of soaring into the regions of fancy, although we affirm each of these stars not only to be a sun with a system of planets and comets moving round it, but that it is highly probable each star is at least equal, both in brilliancy and magnitude, to the sun himself. And if it once be admitted that each star is the centre of a system, and has planets or earths revolving round it in the same manner as our sun has, is it not agreeable both to reason and analogy, to suppose these planets inhabited by rational creatures? When every part of matter upon which we have any opportunity of making observations, is found fitted for the habitation and support of

* The period in which the star Algol goes through its variations is two days twenty-one hours.

living creatures peculiar to itself; when we meet with no part of nature lying waste and useless; and when we find that not only seas, lakes and rivers, mountains and valleys, trees and herbs, grasses and the animals that feed upon them, teem with life; but even the blood and humours of animals, when alive as well as dead, support their respective inhabitants; shall we, with such scenes before our eyes, and in direct opposition, as it were, to the voice of nature, indulge the contracted and unreasonable notion, that the millions of globes which compose the universe are barren and void? Is it not more rational to suppose them the abodes of intelligent beings; of beings capable of loving and adoring their Creator, provided with every thing necessary for their comfort and support, and possessed of capacities necessary for social intercourse and active life?

Where things do not admit of mathematical certainty, moral certainty ought to be indulged, especially when aided by the analogy of things which are both known and natural. It would almost be as irrational to suppose animals with eyes destined to live in eternal darkness, or without eyes to live in perpetual light, as to imagine space illuminated where there is nothing to be acted upon. The fixed stars were surely not created merely for the purpose of enlightening a void! All great astronomers, with Newton at their head, have maintained that the stars are all suns, and surrounded with planetary bodies which they enlighten, warm, and cherish in the same manner as the sun does the bodies which circulate round him. And the celebrated Huygens says, "Why should we conclude that our star (that is the sun) has better attendance than others? They must all have their planets and animals; nay their rational creatures too."—But we forbear to proceed further in the path of speculation on this sublime subject, although it is almost impossible to avoid it; for when we reflect on the millions of millions of *worlds* placed at the distance of millions of miles from each other, and each of these worlds inhabited by millions of *rational creatures*, formed for never-ending felicity, the idea though delightful must necessarily be vague and indefinite. Really when indulging such contemplations, we can scarcely help acknowledging, that all our science is as nothing, and that we have yet to be initiated in the principles of a new notation, which may enable us to comprehend these astonishing numbers.

My soul unused to stretch her powers,
In flights so daring, drops her weary wing,
And seeks again the known accustomed spot,
Drest up with sun and shade, and lawns, and streams,
A mansion fair and spacious for its guest,
And full replete with wonders.

BARBAULD.

OF ECLIPSES.

Of all the various phenomena of the heavens there are none which have created so much curiosity, excited so much interest, or caused so great terror throughout the world, as eclipses of the sun and moon; and to those who are unacquainted with the principles of astronomy there is nothing perhaps which appears more extraordinary than the accuracy with which they can be predicted.

In the earlier ages of the world, before science had enlightened the minds of men, appearances of this kind were generally regarded as alarming deviations from the established laws of nature; and but few, even among philosophers themselves, were able to account for these extraordinary appearances. At length, when men began to apply themselves to observations, and when the motions of the celestial bodies were better understood, their phenomena were not only found to depend upon a regular cause, but to admit of a natural and easy solution. There are, however, nations that still entertain the most superstitious notions respecting eclipses, particularly the Mexicans and Chinese, whose conduct on the appearance of a phenomenon of this kind is well described in the following lines:—

> Thus when the infant moon her circling sphere
> Wheels o'er the sun's broad disk, her shadow falls
> On earth's fair bosom; darkness chills the fields,
> And dreary night invests the face of heaven.
> Reflected from the lake full many a star
> Glimmers with feeble languor. India's sons
> Affrighted in wild tumult rend the air.
> Before his idol god with barb'rous shriek
> The Brachman* falls: when soon the eye of day
> Darts his all-cheering radiance, from the gloom
> Emerging. Joy invades the wond'ring crowd,
> And acclamation rushes from the tongues
> Of thousands, that around their blazing pile
> Riot in antic dance and dissonant song.
>
> ZOUCH.

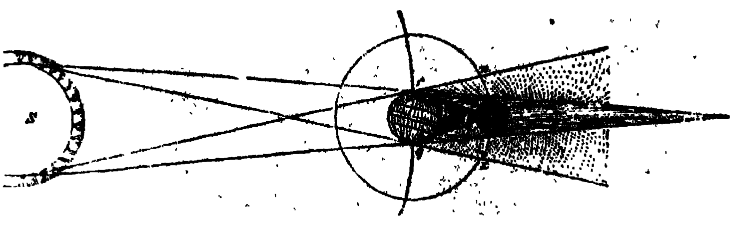
Many instances are to be found, not only in ancient, but even in comparatively modern history, where the superstition of the times has continued to connect the records of eclipses with the details of some remarkable event, which either happens soon after or during their continuance. But these details being foreign to the nature of the present work, we shall proceed to give an account of the causes, and various kinds of eclipses of the sun and moon,

> Teach me the various labours of the moon,
> And whence proceed th' eclipses of the sun.

* Although the Chinese perform the most ridiculous and superstitious ceremonies during the time of an eclipse, yet they can calculate them with the greatest precision.

As every planet belonging to the solar system, both primary and secondary, derives its light from the sun, it must cast a shadow towards that part of the heavens which is opposite to the sun. This shadow is of course nothing but a privation of light in the space hid from the sun by the opaque body, and will always be proportionate to the relative magnitudes of the sun and planet. If the sun and planet were both of the same size, the form of the shadow cast by the planet would be that of a cylinder, the diameter of which would be the same as that of the sun or planet, and it would never converge to a point. If the planet were larger than the sun, the shadow would continue to spread or diverge; but as the sun is much larger than the greatest of the planets, the shadows cast by any one of these bodies must converge to a point, the distance of which from the planet will be proportionate to the size and distance of the planet from the sun. The magnitude of the sun is such that the shadow cast by each of the primary planets always converges to a point before it reaches any other planet; so that not one of the primary planets can eclipse another. The shadow of any planet which is accompanied by satellites may, on certain occasions, eclipse these satellites; but it is not long enough to eclipse any other body. The shadow of a satellite or moon may also, on certain occasions, fall on the primary and eclipse it.

Eclipses of the sun and moon happen when the moon is near her nodes, that is, when she is either in the plane of the ecliptic or very near it. Those of the sun happen only at *new moon*, or when the moon is in conjunction with the sun; whilst those of the moon happen at the time of *full moon*, or when the moon is in opposition to the sun. The sun, earth, and moon, must therefore always be nearly in the same straight line at the time of an eclipse; and conversely, when these three bodies are nearly in a straight line, an eclipse must take place. Hence, it is evident, that an eclipse happens in consequence of one of the two opaque bodies, the earth and the moon, being so placed as to prevent the sun's light from falling on the other.—See the following figure, which represents the moon passing through the dark shadow of the earth, as she moves in her orbit *n z*, while the earth moves in the ecliptic *r q*.



The interposition of the moon between the sun and the earth produces an eclipse of the sun; and the interposition of the earth between the moon and the sun, so that its shadow falls on the moon, produces

an eclipse of the moon. On these principles the whole phenomena of eclipses depend, and admit of complete explanation.

If the moon's orbit were coincident with the plane of the ecliptic, the moon's shadow would fall upon the earth, and occasion a *central eclipse* of the sun at every conjunction, or new moon; whilst the earth's shadow would fall on the moon, and occasion a total eclipse of that body at every opposition or full moon. For as the moon would then always move in the ecliptic, the centres of the sun, earth, and moon, would all be in the same straight line at both of these times. But the moon's orbit is inclined to the ecliptic, and forms with it an angle of about 5° 10′; and, therefore, the moon is never in the ecliptic except when she is in one of her *nodes:* hence, there may be a considerable number of conjunctions and oppositions of the sun and moon without any eclipse taking place.

The moon is always at some distance from the ecliptic, except when she is in one of her *nodes;* and this distance is called her *latitude*, which is north or south, according as the moon is on the north or south side of the ecliptic. Now if the moon has any latitude, there cannot be a *central* eclipse, for this can only happen when the moon is in one of her nodes at the moment of conjunction, which is very seldom the case; and, of course, very few central eclipses of the sun have taken place since the creation of the world.* But the section of the earth's shadow (through which the moon passes when she is eclipsed) being much larger than the disc of the moon, the moon may be *totally* eclipsed, although she be at some distance from her node at the time of opposition; but its duration will be the greater the nearer she is to the node. An eclipse of the *sun* may also happen although the moon be at some distance from her node at the time of conjunction; but its form, as well as its duration, depend very much upon that distance. This circumstance has occasioned the division of eclipses into central, total, annular, and partial.

As the meaning of these terms must be obvious to the reader, it is almost unnecessary to give an explanation of them.

A central eclipse, is that in which the centre of the shadow falls on the centre of the body which is eclipsed.

A total eclipse is the obscuration of the whole body eclipsed.

An annular eclipse is that in which the whole of the body eclipsed is hid, except a ring round its edge, which remains luminous.

A partial eclipse is that in which part of the eclipsed body is hid from view.

The following figure represents a partial eclipse of the sun, which will be visible to that tract of the earth marked *n p o*, the line *m n* marks when the greatest obscuration.

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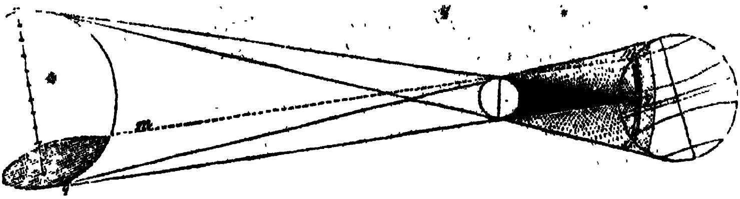
* One of the most remarkable eclipses of this kind which has ever happened, was visible in Britain and several other countries, on the 7th of September, 1820.



If the distance be very small, the eclipse will be the greater and continue the longer; but no eclipse of the sun can be either *central* or total, except the moon be in the very node at the time of conjunction. But should she be in this situation, when she is at her least distance from the earth, and the earth, at the same time, at its least distance from the sun, then the eclipse will not only be central but *total*, and continue so for a few minutes. But if the moon happens to be at her greatest distance from the earth, and the earth at its greatest distance from the sun, the eclipse will be annular, or a small space round the sun's centre only will be hid from view, and a bright lucid ring round his edge will remain visible.

If the moon be less than 17$\frac{1}{3}$ degrees from either node at the time of conjunction, her shadow will fall more or less upon the earth, according as she is more or less within this limit; and, of course, the sun will suffer a *partial* eclipse. And if she be less than 12$\frac{1}{2}$ degrees from either node at the time of opposition, she will pass through more or less of the earth's shadow, according as she is more or less within these lines, and of course she will suffer an eclipse.

As these limits form but a small part of the moon's orbit, which is 360 degrees, eclipses happen but seldom; however in no year can there be fewer than two, and there may be seven of the sun and moon together—but taking one year with another, there are about four each year. But as the sun and moon spend as much time below the horizon of any place as above it, half the number of the eclipses will be *invisible* at any particular place, and consequently there will be only *two* eclipses visible in a year at that place, the one of the sun and the other of the moon.*

Every eclipse, whether of the sun or moon, is *visible* at some place of the earth's surface, and invisible at others; for the rational horizon of every place divides both the earth and heavens into two equal portions or hemispheres; and as no celestial body can be seen except it be above the spectator's horizon, it follows that any eclipse which is visible in the one hemisphere cannot be visible in the other, because the body which is eclipsed is below the horizon of that other. If a lunar eclipse, for example, happens at any hour of the night, between

* If there be seven eclipses in any year, five of them must be of the sun and two of the moon.

the time of sun-setting and sun-rising, at any particular place, it will be visible there and invisible to the inhabitants of the opposite hemisphere, who have the sun above their horizon at that time; for the sun and moon are in opposite parts of the heavens at the time of a lunar eclipse. And with respect to solar eclipses, it is evident that they can only be seen at any place when the sun is above the horizon of that place. There is, however, a difference with regard to the visibility of a solar and lunar eclipse; for an eclipse of the moon has the same appearance to all the inhabitants of that hemisphere to which the moon is visible at the time, owing, in part, to the small distance of the moon from the earth. But an eclipse of the sun may be visible to some places and invisible to others in the same hemisphere of the earth, because the moon's shadow is small in comparison of the earth; for its breadth, excluding the penumbra, is only about 180 miles even in central eclipses.* Hence those places which are considerably distant from the path of the shadow will either have no eclipse at all, or a very small one; while places near the middle of the shadow will have the greatest possible. There is also a difference in the absolute time at which a solar eclipse happens at the various places where it is visible; for it appears more early to the western parts, and later to the eastern, on account of the motion of the moon (and of course her shadow) from west to east.

In most solar eclipses the moon's disc may be observed by a telescope to be covered by a faint light, which is attributed to the reflexion of light from the illuminated part of the earth. When the eclipses are total, the moon's limb is surrounded by a pale circle of light, which some astronomers consider as an indication of a lunar atmosphere, but others, as occasioned by the atmosphere of the sun; because it has been observed to move equally with the sun and not with the moon.

Dr. Halley, in describing a central eclipse of the sun, which happened at London in April, 1715, says, that although the disc of the sun was wholly covered by the moon, a luminous ring of a faint pearly light surrounded the body of the moon the whole time; and its breadth was nearly a tenth of the moon's diameter.

In lunar eclipses, the moon seldom disappears entirely; and on some occasions, even the spots may be distinguished through the shade; but this can only be the case when the moon is at her greatest distance from the earth at the time of the eclipse, for the nearer the moon is to the earth the darkness is the greater. In some instances, the moon has disappeared entirely; and the celebrated astronomer Heraclius, has taken notice of one where the moon could not be seen even with a telescope, though the night was remarkably clear.

Although eclipses of the sun and moon were long considered by the ignorant and superstitious as presages of *evil*, yet they are of the greatest use in astronomy, and may be employed to improve some of

* A penumbra is the faint shadow produced by an opaque body when opposed to a luminous one.

the most important and useful of the sciences. By eclipses of the moon the *earth* is proved to be of a *globular* form, the sun to be *greater* than the *earth*, and the *earth* greater than the *moon*. When they are similar in all their circumstances, and happen at considerable intervals of time, they also serve to ascertain the real period of the moon's motion. In geography, eclipses are of considerable use in determining the longitude of places, and particularly eclipses of the moon, because they are oftener visible than those of the sun, and the same eclipse is of equal magnitude and duration at all places where it is seen. In chronology, both solar and lunar eclipses serve to determine exactly the time of any past event.

> We, in the dark eclipse, with filial awe
> Trace the all-gracious Parent of the spheres;
> Their distances and their proportion learn;
> Extending navigation; securing
> The mariner thro' the tremendous waves.
>
> EUDOSIA.

For the purpose of finding the longitude at places on the earth, eclipses of Jupiter's satellites are found much more useful than eclipses of the moon; not only on account of their happening more frequently, but on account of their instantaneous commencement and termination.

When Jupiter and any of his satellites are in a line with the sun, and Jupiter between the satellite and the sun, it disappears, being then eclipsed, or involved in his shadow. When the satellite goes behind the body of Jupiter, with respect to a spectator on the earth, it is said to be *occulted*, being hid from our sight by his body, whether in his shadow or not. And when the satellite comes into a position between Jupiter and the sun, it casts a shadow on the face of that planet, which is seen by a spectator on the earth as an obscure round spot. Lastly, when the satellite is in a line with Jupiter and the earth, it appears on his disc as a round black spot, which is termed a transit of the satellite.

As these phenomena appear at the same moment of *absolute* time at all places on the earth to which Jupiter is then visible, but at different hours of *relative* time, according to the distance between the meridian of the places at which observations are made, it follows that this difference of time converted into degrees will be the difference of longitude between those places.* Suppose, for example, that a person at London observed an eclipse to begin at 11 o'clock in the evening, and that a person at Barbadoes observed the same at 7 o'clock in the evening, it is certain the eclipse was seen by both persons at the same moment of absolute time, although there is four hours' difference in their manner of reckoning that time: and this converted into degrees (at the rate of 15 degrees to an hour), is the

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* *Absolute* time is that which is computed from the same moment; *relative* is that which is computed from different moments.

difference of longitude between these two places—therefore Barbadoes is 60 degrees *west* from London, the time not being so far advanced there as at London.

Another phenomenon, somewhat similar to an eclipse, sometimes takes place, by which the longitude of places may be determined, although not quite so easily, nor perhaps so accurately, as by the eclipses of Jupiter's satellites. This is the hiding or obscuring of a fixed star or planet by the moon or other planet, which takes place when the moon or planet is in conjunction with the star. Appearances of this kind are termed occultations. They are very little attended to except by practical astronomers, who employ them for the correction of the lunar tables, and settling the longitude of places, as already stated.

ON LIGHT.

Fairest of beings! first created light!
Prime cause of beauty! for from thee alone
The sparkling gem, the vegetable race,
The nobler worlds that live and breathe their charms,
The lovely hues peculiar to each tribe,
From thy unfading source of splendour draw
In thy pure shine, with transport I survey
This firmament, and these her rolling worlds
Their magnitudes and motions.

MALLET.

The nature of Light has been the subject of speculation and conjecture among philosophers, from the first dawnings of philosophy to the present day. But of all the conjectures which have been advanced on this curious and interesting subject, there is scarcely one supported by evidence sufficient to entitle it to preference over the other. There are, however, two opinions on this subject which have prevailed more generally than any of the others, and therefore, it may be proper to notice them here, although the design of the present work is rather to state what is known respecting any phenomenon, than to indulge in conjectures concerning it.

The celebrated Huygens considered light as a subtle fluid filling space, and rendering bodies visible by the undulations into which it was thrown. According to this theory, when the sun rises it agitates this fluid, the undulations gradually extend themselves, and at last striking against our eyes, we see the sun. This opinion of Huygens was adopted by Euler, one of the best mathematicians that ever lived, who exerted the whole of his consummate mathematical skill in its defence.

Sir I. Newton and many other distinguished philosophers consider light as a substance consisting of small particles, constantly separating from luminous bodies, moving in straight lines, and rendering other bodies luminous by passing from them and entering the eye. Newton has been at great pains to establish this theory, and has certainly

shown that all the phenomena of light may be mathematically deduced from it.

While Huygens and Euler have attempted to support their hypothesis, rather by starting objections to Newton's, than by bringing forward direct proofs, Newton and his disciples, on the contrary, have shown that the known phenomena of light are *inconsistent* with the undulations of a fluid, and that on such a supposition there can be no such thing as darkness at all. They have also brought forward a great number of direct arguments in support of their theory, which it has been impossible to answer.* But without giving a decided preference to any theory, we shall proceed to state some of its properties.

Roemer, a Danish astronomer, while engaged in making observations on the satellites of Jupiter, found that in eclipses they emerged from the shadow at certain times a few minutes later, and at others a few minutes sooner than they ought to have done according to the tables, which had been previously constructed to shew the times of their revolutions, eclipses, &c. On comparing these apparent irregularities together, he found that the eclipses happened before or after the computed time, according as the earth was nearer to or farther from Jupiter. Hence he formed the ingenious conjecture, which was soon demonstrated to be the case, that the motion of light is not instantaneous, as was then generally believed, but that it required a certain portion of time, to pass from the luminous body to the eye of the observer. According to Roemer's calculation, it was about *seven minutes* in traversing the radius of the earth's orbit; but it has since been found, that when the earth is exactly between Jupiter and the sun, his satellites are eclipsed about 8¼ minutes sooner than the time found by the tables; but when the earth is nearly in the opposite point these eclipses happen about 8¼ minutes later than that determined by the tables. It is therefore concluded that light takes up about 16½ minutes of time to pass over a space equal to the diameter of the earth's orbit, which is at least one hundred and ninety millions of miles; it therefore moves at the rate of nearly 200,000 miles per second, which is about 10,300 times faster than the earth in its orbit, and 1,550,000 times quicker than a cannon ball.†

> Behold the light emitted from the sun!
> What more familiar, and what more unknown?
> While by its spreading radiance it reveals
> All Nature's face, it still itself conceals.
> See how each morn it does its beams display,
> And on its golden wings bring back the day!

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* M. Delaval maintains, that all light is reflected by white particles, and coloured in its transmission. No transparent medium reflects any light when examined within a blackened bottle; this is shewn by experiments on 66 kinds of fluids, and on many kinds of glasses, and other substances. For this, and for the colours of the sea, M. Delaval proposes a very singular theory; but those who wish to become particularly acquainted with it, must consult his work on the permanent colours of opaque bodies.

† The real time which light takes to pass from the sun to the earth is 8 minute 13 seconds.

How soon the effulgent emanations fly
Thro' the blue gulf of interposing sky!
How soon their lustre all the region fills,
Smiles on the valleys, and adorns the hills:
Millions of miles, so rapid is their race,
To cheer the earth, they in few minutes pass.
Amazing progress! At its greatest stretch,
What human mind can this swift motion reach?

BLACKMORE.

The velocity of light being known, it is easy to know the time it requires to arrive at the earth from any of the planets, or even the fixed stars if their distance be known. For it has been ascertained, that the reflected light of the planets and satellites, travels with the same velocity as the direct light of the sun or fixed stars; and that the velocity is the same from whatever distance it comes.

The discovery of Roemer has been completely confirmed by another most important discovery made by our countryman Dr. Bradley, while engaged in making a series of observations, with a view to determine the annual parallax of the fixed stars. This celebrated astronomer found that the aberration or difference between the true and apparent place of a fixed star, is occasioned by the progressive motion of light, combined with the motion of the earth in its orbit; and that this *aberration* when greatest amounted to 20 ·232. Now the earth describes an arc of 20″·232, in 8′ 13″, the time that light takes to pass over the semidiameter of the earth's orbit. This circumstance, therefore, not only affords one of the most convincing proofs of the motion of the earth in its orbit, but entirely overthrows both the Ptolemaic and Tychonic systems, and completely establishes the motion of the earth.

As the rays of light are known to proceed only in straight lines from luminous bodies, and as the earth is constantly moving forward in its orbit, it is evident that a ray of light proceeding from any celestial body will impinge on the earth at a different point from what it would have done had the earth been stationary. It is therefore necessary, in making astronomical observations with nicety, to make allowance for the aberration. When a fixed star or planet, for example, is seen through a tube or telescope, the tube does not point exactly to the *true* place of the star or planet, but to its *apparent* place, which is always more advanced in the direction we are moving than its true place, by a quantity equal to the aberration of the object.* But this will, perhaps, be better understood by the following illustration, which is given by M. Maupertius in his Elements of Geography.

"The direction," says he, "in which a gun must be pointed to strike a bird in its flight, is not exactly that of the bird, but of a point a little before it, in the path of its flight; and that so much, the more as the flight of the bird is more rapid, with respect to the flight

* The aberration not only affects the longitude of a star or planet, but also its latitude, declinations, and right ascension.

of the shot. In this way of considering the matter, the flight of the bird represents the motion of the earth, and the flight of the shot the motion of the light proceeding from the object."

Many philosophers have attempted, not only to compare the light of the stars with that of the sun, but also to ascertain their distances by comparisons of this kind.

The Rev. Mr. Mitchell, in an elaborate and ingenious paper in the Transactions of the Royal Society, states, that our sun would still appear as luminous as the star Sirius, although removed to 400,000 times his present distance; and that the fixed stars cannot be nearer than this, if they be equal to the sun in lustre and magnitude, and that they are so is the opinion of the most celebrated astronomers of the present day. Euler, who has already been mentioned, makes the light of the sun equal to 6,500 candles at one foot distance; the moon equal to one candle at $7\frac{1}{2}$ feet distance; Venus to one at 421 feet; and Jupiter to one at 1320 feet. From this comparison it follows, the light of the sun exceeds that of the moon 364,000 times.—It is therefore no wonder that the attempts which have been made by some philosophers to condense the light of the moon by lenses, have been attended with so little success. For, should one of the largest of these lenses even increase the light of the moon one thousand times, still, in this increased state, it will be three hundred and sixty-four times less than the intensity of the common light of the sun.

The intensity of light has been found to vary as the square of the distance; for, if an object be placed one foot distant from a candle, it will receive four times more light than when it is removed to double the distance; nine times more than when it is removed to three times the distance, and so on. The refraction, &c. of light will be noticed when treating of the atmosphere.

OF THE AURORA BOREALIS.

Silent from the north
A blaze of meteors shoots: ensweeping first
The lower skies, they all at once converge
High to the crown of heaven, and all at once,
Relapsing quick, as quickly reascend,
And mix, and thwart, extinguish, and renew,
All ether coursing in a blaze of light.

THOMSON.

The Aurora Borealis, or Northern Lights, are luminous meteors, which sometimes appear in the northern part of the heavens in the winter season, and particularly in frosty weather. They are usually of a reddish colour, inclining to yellow, but they frequently send out coruscations of pale whitish light. These seem to rise from the horizon in a pyramidical form, and move backwards and forwards with a tremulous undulating motion; but on some occasions they shoot to the zenith with the greatest velocity, and then form themselves

into the most whimsical figures. This has led M. Godin to suppose, that most of the extraordinary meteors and prodigies which are stated in history to have been seen in the skies, such as battles, and the like, may probably enough have been produced by particular forms assumed by Aurora Borealis.

From look to look, contagious thro' the crowd
The panic runs, and into wondrous shapes
Th' appearance throws: armies in meet array
Throng'd with aerial spears and steeds of fire,
Till the long lines of full-extended war,
In bleeding fight commixt, the sanguine flood
Rolls a broad slaughter o'er the plains of heaven.
As thus they scan the visionary scene,
On all sides swells the superstitious din,
Incontinent, and busy Frenzy talks
Of blood and battle, cities overturn'd,
And late at night in swallowing earthquake sunk,
Or hideous wrapt in fierce ascending flame;
Of sallow famine, inundation, storm,
Of pestilence, and every great distress;
Empires subvers'd, when ruling Fate has struck
Th' unalterable hour even Nature's self
Is deem'd to totter on the brink of time.
Not so the man of philosophic eye,
And inspect sage, the waving brightness he
Curious surveys, inquisitive to know
The causes and materials, yet unfix'd,
Of this appearance, beautiful and new.

THOMSON

This kind of meteor never appears near the equator; but has frequently been seen towards the south pole, as well as the north.

Forster, in the account of his voyage round the world with Captain Cook, says he observed them for several nights together, in sharp frosty weather, and that they had much the same appearance as those observed in the north, except that they were of a lighter colour.

In the Shetland Islands these phenomena are the constant attendants of clear evenings, and afford great relief to the inhabitants in the long and gloomy nights of winter experienced in this part of the world.

The same kind of appearances are also seen in the northern parts of Sweden and Lapland, where they are particularly beautiful, and afford light to travellers during the whole night.

By dancing meteors then, that ceaseless shake
A waving blaze refracted o'er the heavens,
And vivid moons, and stars that keener play
With keener lustre from the glossy waste
Even in the depth of *Polar Night* they find
A wondrous day: enough to light the chase,
Or guide their daring steps to Finland fairs.

THOMSON.

In Hudson's Bay the Aurora Borealis spread a variegated splendour

over the whole sky, not to be defaced even by the splendour of the full moon. In the north-east parts of Siberia these northern lights are observed to begin with single bright pillars, rising in the north, and almost at the same time in the north-east, which gradually increasing, comprehend a large space of the heavens, rush about from place to place, with incredible velocity, and finally almost cover the whole sky up to the zenith, producing an appearance, as if a vast tent were expanded in the heavens, glittering with gold, rubies, and saphires. A more beautiful spectacle cannot be painted; but no person could behold it for the first time without terror. For, however grand the illumination may appear, it is attended with as much hissing, crackling, and tumult, as if the largest fire-works were playing off. The hunters who pursue the white and blue foxes on the confines of the icy sea, are often overtaken in their courses by these northern lights; their dogs are then so much frightened, that they will not move, but lie obstinately on the ground till the noise has passed.

It is chiefly in the arctic regions that the Aurora Borealis are most striking in their appearance. In England it is only their extremities that are seen, and even these have been noticed very seldom: for there are none recorded in our annals between the appearance of the remarkable one of Nov. 14th, 1574, and the surprising one of March 6th, 1716, which appeared for three nights successively. This one was visible from the west of Ireland to the confines of Russia and east of Poland, and from the 30th degree of latitude, over almost all the north of Europe; and in all places, at the same time, it exhibited the same wonderful appearances. Father Boscovich calculated the height of an Aurora Borealis which appeared on the 16th December, 1737, and found that it was 825 miles; and the celebrated Bergman, from a mean of thirty computations, makes the average height of the Aurora Borealis 70 Swedish or 469 English miles. But Euler and some other philosophers suppose their height to be several *thousand* miles

Aurora Borealis were long considered by the ignorant and superstitious as portending war, pestilence, and famine. And this was not only the opinion of the inhabitants of the northern islands, but even the inhabitants of this country were alarmed at their appearance.

When the splendid Aurora Borealis of 1716 first made its appearance, it was viewed with the greatest consternation by the vulgar; and considered by them as marking the introduction of a foreign race of princes into this country.* Since that time, these meteors have been so common that they have not excited any particular interest, and are now viewed with the greatest indifference by all classes of society.

Many conjectures have been made, at various periods, respecting the cause of this phenomenon; but since the identity of lightning

* George the First came to the throne of Great Britain on the 1st of August, 1714.

with the electric fluid has been ascertained, philosophers have been naturally led to seek for the explication of aerial meteors in the principles of electricity; and there is now little doubt but most of them, and especially Aurora Borealis, are electrical phenomena. Besides the more obvious and known appearances which constitute a resemblance between this meteor and the electric matter by which lightning is produced, it has been observed, that the Aurora Borealis produces a very sensible fluctuation in the magnetic needle; and that when it has extended lower than usual into the atmosphere, the flashes have been attended with various sounds of rumbling and hissing, especially in Russia and the other northern parts of Europe.

Mr. Canton, soon after he had obtained electricity from the clouds, offered a conjecture that the Aurora is occasioned by the flashing of electric fire from positive towards negative clouds at a great distance, through the upper part of the atmosphere, where the resistance is least; and this appears chiefly in the northern regions, as the alteration in the heat of the air in those parts is the greatest.

Signior Beccaria supposes that there is a constant and regular circulation of the electric fluid from north to south; and he thinks, that the Aurora Borealis may be this electric matter, performing its circulation in such a state of the atmosphere as renders it visible.—Dr. Franklin thinks, that the electric fire discharged into the polar regions, from many miles of vapour raised from the ocean between the tropics, accounts for the Aurora Borealis; and that this phenomenon appears first, where it is first put in motion, namely, in the northern regions, and the appearance proceeds southward, though the fire really moves in the opposite direction. Several other eminent philosophers have advanced conjectures respecting the cause of this phenomenon, but our limits will not permit us to insert them.*

There is another luminous appearance occasionally seen in the heavens after sun-set, and before sun-rise, which somewhat resembles the milky way, but of a fainter light. This phenomenon is called the zodiacal light, because it is only to be seen in the zodiac. Its figure resembles an inverted cone or pyramid, with its base toward the sun, and its axis lying along the zodiac, somewhat inclined to the horizon. It was first discovered by Cassini, in the year 1683; but there is some reason to think it had been observed before that period. The length of this phenomenon, taken from the sun upwards to its vertex, varies from 45 degrees to 100, and even 120 degrees. The season most favourable for observing it, is the beginning of March after sun-set. But its aspect is very different in different years. One of the most brilliant appearances of it was observed at Paris on the 16th of February, 1769.

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* Seamen who have often visited the north seas consider the appearance of Aurora Borealis as indicative of a gale of wind.

Various opinions have been advanced respecting the cause of the zodiacal light, as well as the Aurora Borealis; but the greater number of philosophers agree in ascribing both phenomena to the same cause, namely, the electric fluid.

But the celebrated M. de Mairan, who has written a treatise expressly on the Aurora Borealis, supposes that the zodiacal light causes the Aurora Borealis; and that this light is nothing more than the sun's atmosphere, which is thrown off by means of the rotation of that luminary on his axis to such a distance, as to strike on the upper part of the earth's atmosphere, and produce the luminous appearance which we call the zodiacal light. And as this is chiefly collected towards the polar regions, by means of the diurnal revolution of the earth, it will produce the Aurora Borealis.

OF RAINBOWS, PARHELIA,* &c.

> —— Refracted from yon eastern cloud,
> Bestriding earth, the grand etherial bow;
> Shoots up immense; and every hue unfolds,
> In fair proportions running from the red,
> To where the violet fades into the sky.
> Here, awful Newton, the dissolving clouds
> Form, fronting on the sun thy showery prism;
> And to the sage-instructed eye unfold
> The various twine of light, by thee disclosed
> From the white mingling maze. THOMSON.

Besides the Aurora Borealis, there are several other beautiful phenomena occasionally seen in the heavens. Among these may be ranked the Rainbow; which is, unquestionably, the most beautiful meteor with which we are acquainted.

It is never seen but in rainy weather, and in that point of the heavens which is opposite to the sun, being occasioned by the refraction and reflection of his rays falling on the drops of rain as they descend to the earth. There are frequently two bows to be seen at the same time—an interior and an exterior one. The interior is the brightest, being formed by the rays of the sun falling on the *upper parts* of the drops of rain; for a ray of light entering the upper part of a drop of rain, will, by refraction, be thrown upon the inner part of the spherical surface of that drop, whence it will be reflected to the lower part of the drop, where, undergoing a second refraction, it will be bent toward the eye of the spectator. Hence, the rays which fall upon the interior bow come to the eye after *two refractions* and one reflection; and the colours of this bow from the upper part, are *red*, orange, yellow, *green*, *blue*, indigo, and violet. The exterior bow is

* Although we have given a short account and representation of the Rainbow in the supplementary part of this work, we have deemed it necessary to give a still more popular account of it here.

formed by the rays of the sun falling on the *lower* parts of the drops of rain; these rays also undergo two refractions; one when they enter the drops, and another when they emerge from them to proceed to the eye: but they suffer two, or more, reflections in the interior surface of the drops; hence, the colours of these rays are not so strong and well defined as those in the interior bow, and appear in an inverted order; viz. from the *under* part they are *red*, orange, yellow, green, blue, *indigo*, and *violet*.

The rays which fall on the drops that produce the interior bow proceed to the eye of the spectator in a direction, that makes an angle of about 42 degrees with the direction in which they entered the drops, and those that form the exterior bow at an angle of about 54 degrees.*

This may be proved by a simple experiment, as follows: let a glass globe, filled with water, be suspended in the sun-shine, and let a person turn his back to the sun, and view the globe at such a distance that the part of it which is farthest from the sun may appear of a full red colour; then will the rays which come from the globe to the eye make an angle of 42 degrees with the sun's direct rays; and, if the eye remain in the same position, while another person gradually lowers the globe, the orange, yellow, and other colours, will appear in succession as in the interior rainbow. Again: if the glass globe be elevated, till the side nearest the sun appear *red*, the rays which come from the globe to the eye will make an angle of about 50 degrees; and if the globe be again gradually raised as before, the rays will successively change from red to orange, yellow, &c. as in the exterior bow.

All rainbows are arcs of equal circles, and, consequently, are all equally large, though we do not always see an equal quantity of them: for the eye of the spectator is the vertex of a cone, and its circular base is the rainbow, of which one half is the greatest portion that can be seen at once.

Although lunar rainbows have been observed, yet they occur but very seldom. A very brilliant and remarkable one was seen in the year 1710, at Glopwell Hall, in Derbyshire, about eight o'clock in the evening. The moon had passed the full about twenty-four hours, and the evening had been rainy; but the clouds were dispersed, and the moon then shone very clear.

This *iris lunaris* had all the colours of the solar iris exceedingly beautiful and distinct, but faint in comparison with those that are seen when the sun is shining very bright; as must necessarily have been the case, both from the different beams by which it was occasioned, and the disposition of the medium. What most surprised the observer was, the largeness of the arc, which was not much less than that produced by the sun.

Several complete and concentric solar rainbows have sometimes

* The angle which the *emerging* ray makes with the incident ray in the *Interior* bow is 42° 2′ for the *red*, and 40° 17′ for the *violet*; and for the *Exterior* bow, these angles are 50° 57′ and 54° 7′.—Therefore, the space between the bows is about 9 degrees broad.

been observed in mountainous countries. This extraordinary phenomenon, first seen by Don Ulloa and his companions in the wild heaths of Pambamarca, which he describes as follows.—"At the side opposite to that where the sun rose on the mountain, at the distance of about sixty yards from the spot where we were standing, the image of each of us was represented as if in a mirror; three concentric rainbows, the last or more exterior colour of one of them touched the first or interior colours of the following one, being centred on the head. On the outside of these, at an inconsiderable distance from them, was seen a fourth arc, purely white. They were all perpendicular to the horizon; and as any one of us moved from one side to the other, he was accompanied by the phenomenon, which preserved the same order and disposition. But what seemed most remarkable was, that, although six or seven persons were standing close together, each of us saw the phenomenon as it regarded himself, but did not perceive it in the others."

A similar phenomenon is described by Mr. Hagarth, F.R.S. as having been seen by him on the evening of the 13th of February, 1780, when ascending a mountain at Rhealt, in Denbighshire.

Another singular phenomenon is sometimes to be seen in the heavens, which very much resembles the sun; and, on that account, it has received the name of Parhelion, or mock sun. An extraordinary appearance of this kind was seen near Marienberg, in Prussia, on the 5th of February, 1674. It was of the same apparent size with the sun, which was several degrees above the horizon at the time, and shone with great lustre. The mock sun appeared under the real one, and seemed to increase in lustre as the true sun descended to the horizon, insomuch, that the reddish colour it first exhibited completely vanished; and it put on the genuine solar light, in proportion as the disc of the real sun approached it. At last the real sun immerged into the counterfeit sun, and remained alone. This phenomenon was considered the more extraordinary, as it appeared perpendicularly under the sun, instead of being to the right or left of it, as parhelia usually are, and of a colour so different from that which mock suns usually exhibit.

One or two appearances of the same kind have been seen in England since that time. On the 28th of August, 1698, about eight o'clock in the morning, there was seen at Sudbury, in Suffolk, the appearance of three suns at the same time, all extremely brilliant. Beneath a dark watery cloud, in the east, the true sun shone with such splendour that the spectators could not look at it; and on each side were the reflections. The circles were not coloured like the rainbow, but white. At the same time, the form of a half moon was visible toward the south, at a considerable distance from the other phenomena, but apparently double the size of the half moon, and of a red colour like that of the rainbow. These phenomena faded away gradually, but continued visible for more than two hours. Two mock suns, an arc of a rainbow, and a halo, were seen at Lyndon, in the county of Rutland, on the 22d of October, 1721, at eleven in the

morning. The parhelia or mock suns were bright and distinct.* They were of a reddish colour towards the sun, but pale or whitish toward the opposite sides, which was also the case with the halo. Still higher in the heavens was an arc of a rainbow, of a curiously inverted form, situated about half way between the halo and the zenith. This arc was as distinct in its colours as the common rainbow, and of the same breadth.

The red colour was on the convex, and the blue on the concave of the arc, which seemed to be about 90 degrees in length; its centre being very near the zenith. On the top of the halo was a kind of inverted bright arc, of considerable extent. This phenemenon was seen on the following day, and again on the 26th of the same month.

Several other phenomena are sometimes to be seen in the heavens, but these are too ephemeral to merit any notice here.

OF THE ATMOSPHERE, AND ASTRONOMICAL REFRACTION.

The earth is surrounded by a thin fluid mass of matter, called the Air or Atmosphere, which revolves with it in its diurnal motion, and goes round the sun with it every year. This fluid is both ponderous and elastic. Its weight is known from the Torricilian experiment, or that of the barometer; and its elasticity is proved by simply inverting a vessel full of air in water.

The atmosphere of the earth's surface being pressed by the weight of all above it, is there pressed the closest together; and therefore the atmosphere is densist of all at the earth's surface; and its density necessarily diminishes the higher up. For each stratum of air is compressed only by the weight of those above it; the upper strata are therefore less compressed, and consequently less dense, than those below them.

The pressure or weight of the atmosphere has been repeatedly determined, by various experiments, to be about fourteen pounds on every square inch of the earth's surface. Hence, the total pressure on the whole surface of the earth is 10,680,000,000 hundreds of millions of pounds avoirdupois.

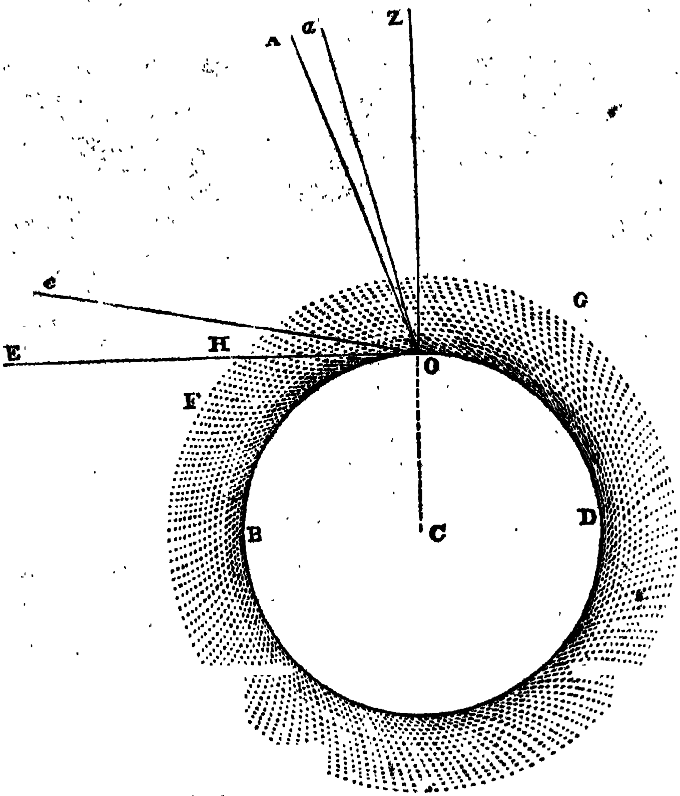
From a number of experiments made on the density of the atmosphere, at various altitudes, by means of the barometer, it has been ascertained, that if heights, from the earth's surface, be taken in arithmetical progression, the density of the corresponding strata of air decrease in geometrical progression. Thus the density of the atmosphere is reduced one-half for every $3\frac{1}{2}$ miles of perpendicular ascent. At seven miles in height, the corresponding density is only one-fourth; at $10\frac{1}{2}$ miles, one-eighth; at 14 miles, one-sixteenth;

* A Halo is an extensive luminous ring, which is sometimes seen to surround the sun and moon, and is supposed to be occasioned by the light of these bodies through the intervening clouds. This appearance is most frequent about the moon.

and so on. Since the density of the air decreases at this rapid rate, it is evident that at a very moderate distance from the surface of the earth, its density would be so much diminished, as to render it incapable of sustaining animal life. From observation and experiment, it is pretty well known that 45 or 50 miles is the utmost height at which the density is capable of refracting a ray of light; and, therefore, this may be considered the altitude corresponding to the least *sensible* degree of density; for, according to the law of its decrease, just stated, the density at this altitude is above 10,000 times less than at the earth's surface.

One of the most extraordinary and useful properties of the atmosphere, is its reflective power, which causes the heavens to appear luminous when the sun shines; for were it not for this power, the whole of the heavens, and every thing on the earth, would appear black, or completely dark, except what the sun's rays directly impinged upon. The stars would be visible by day as well as by night; and we could see nothing except what was fully exposed to the sun. There could be no twilight, and, consequently, the blackest darkness would immediately succeed the brightest sun-shine when the sun sets; and the transition would be equally sudden from the blackest darkness to the brightest sun-shine when the sun rose. But by means of the atmosphere we enjoy the sun's light, reflected from the aërial particles for some time before he rises, and also for some time after he sets. For when the earth, by its revolution on its axis, has turned any particular place away from the sun, the atmosphere above that place will continue to be illuminated for some time. However, as the sun gets farther below the horizon, the less will the atmosphere be illuminated; and when he has got *eighteen* degrees under the horizon, cease to be illuminated, and then all that part of the heavens which is over the place will become dark: for the place will then be turned too far from the sun, and his rays will strike too high on the atmosphere to be refracted or bent downwards at that place. In consequence of the refractive power of the atmosphere, all the heavenly bodies appear higher than they really are; for, on account of the variation in the density of the air, a ray of light in passing through it will be refracted at every instant, and consequently the path of the ray will be a curve. And as an object is always seen in the direction in which the rays of light proceeding from it enter the eye, it is evident every celestial body will appear more elevated above the horizon than it actually is, by a quantity equal to the refraction which a ray of light suffers in passing from it through the atmosphere to the eye of the observer.

When the object is in the zenith, the refraction is quite insensible; but it increases as the altitude of the object diminishes, till it reaches the horizon, and then the refraction is greatest; for the rays which proceed from the object, in that situation, enter the atmosphere more obliquely than in any other, and consequently are more turned out of their course. This will be evident from an inspection of the following figure.



Where B O D represents the surface of the earth, O the place of an observer, and F G H the surrounding atmosphere. A ray of light proceeding from a body, Z, in the zenith, is not refracted; but it proceed from a body at A, it will enter the eye at O, and appear in the direction O *a*; if the body be in the horizon, as at E, the rays proceeding from it will enter the eye at O, and appear to come in the direction *e* O.

On some occasions, the horizontal refraction amounts to 36 or 37 minutes, and, generally, to about 33 minutes, which is equal to the diameter of the sun or moon; and therefore the whole disc of the sun or moon will appear above the horizon, both at rising and setting, although actually below. This is the reason that the full moon has sometimes been seen above the horizon before the sun was set. A remarkable instance of this kind was observed at Paris, on the 19th of July, 1750, when the moon appeared visibly eclipsed, while the sun was distinctly to be seen above the horizon.

At some seasons of the year the sun appears ten minutes sooner above the horizon in the morning, and continues as much longer above

it in the evening, than he would do were there no refraction; and at a mean rate, about seven minutes on any day of the year. The refraction varies, however, very much with the state of the atmosphere. In cold dry weather the air is more dense than in warm weather; consequently the refraction is greater in cold weather than in warm; and for the same reason, it is greater in cold countries than in hot ones.

A remarkable instance of this is mentioned by Dr. Smith in his Optics, where he states, that some Hollanders who wintered in Nova Zembla, in the year 1596, were surprised to find that, after three months' constant darkness, the sun began to appear seventeen days sooner than the time by computation deduced from the latitude, which was 76 degrees. Now this phenomenon can only be accounted for by the extraordinary refraction of the sun's rays in passing through the cold dense air in that climate.

At the same altitudes, the sun, moon, and stars, all undergo the same refraction; for at equal altitudes, the rays which proceed from any of these bodies suffer the same inclination.

The horizontal refraction being the gteatest, causes the sun and moon, at rising and setting, to appear of an oval form; for the lower edge of each being seen through denser atmosphere than the upper edge, is more refracted; consequently, the perpendicular diameter must appear shortened, while the horizontal diameter (which is not affected by refraction) remains the same, and in this way the oval appearance is produced. For the same reason, two fixed stars that are nearer the horizon, and right above each other, appear nearer than when they are high above the horizon; and if they are both in the horizon, but at some distance from each other, then they will appear at a less distance than they really are; for the refraction makes each of them higher, and consequently must bring them into parts of their respective vertical circles which are nearer to each other, because all vertical circles converge and meet in the zenith. Hence, in all astronomical calculations allowance must be made for refraction, before the true altitude of any celestial body can be obtained. Tables, containing this allowance for all altitudes, is to be found in every work on practical astronomy.

The atmosphere not only occasions celestial bodies to appear higher than they really are, by bending the rays of light as they pass through it, but it also affects terrestrial bodies in the same way. The quantity of this refraction is, however, found to vary considerably with the different states of the atmosphere, and is therefore very uncertain. But at a mean rate it may be taken at one-fourteenth part of the distance expressed in degrees in a great circle; or, according to Professor Playfair, it is about one-seventh part of the correction for the earth's curvature, answering to the distance between the observer and the object.*

* For example, suppose the distance between a person and any conspicuous object to be 5 English miles, and he wishes to know how much it is elevated by refraction. The correction for the earth's curvature on this distance is $16\frac{2}{3}$ feet, one-seventh part of which is 2 feet $4\frac{1}{2}$ inches, which it raised by refraction.

Many curious and even whimsical effects of terrestrial refraction are mentioned by various authors; but as our business is chiefly with astronomical refraction, we shall only mention a few of these effects, which have been lately noticed by some of the most intelligent philosophers of the present day.

UNUSUAL REFRACTION OF THE ATMOSPHERE.

Although the phenomena of unusual *refraction* have been often observed by atronomers and navigators, yet they do not seem to have attracted particular notice till the year 1797. The unusual elevation of coasts, mountains, and ships, have been long known under the name of *looming;* and the same phenomena, when accompanied with inverted images, have been distinguished in France by the name of *mirage*.

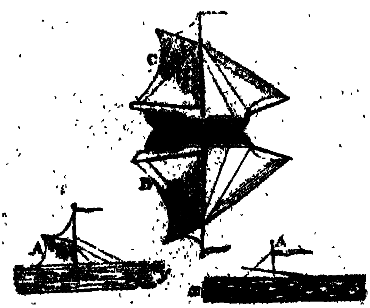
Mr. Huddart seems to have been the first person who described an inverted image beneath the real objects; he accounts for this, and other phenomena of elevation, by supposing that, in consequence of the evaporation of the water, the refractive power of the air is not greatest at the surface of the sea, but at some distance above it, increasing gradually from the surface of the sea to a line, which he calls the *line of maximum density*, and thence diminishing gradually till it becomes insensible.

He then shows, that, in passing through such a medium, the *rays of light* would move in curve lines convex upwards, when they passed above the line of maximum density, and convex downwards when they passed below that line.

Hence, two pencils from the object will arrive at the eye, which will produce an *inverted image* of the object.

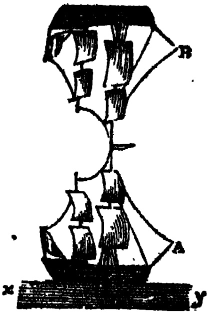
In the year 1798, the Rev. Dr. Vince, of Cambridge, made a series of interesting observations at Ramsgate, on the unusual refraction of the atmosphere. He made his observations with a terrestrial telescope, magnifying between thirty and forty times, when the height of the eye was about twenty-five feet above the surface of the sea. Sometimes the height of the eye was eighty feet; but this produced no variation in the phenomena.

On the 1st of August, between four and eight o'clock, P. M. he saw the topmast of a ship as at A,



above the horizon *xy* of the sea: at the same time, he also discovered in the field of view *two* complete images, B, C, of the ship in the air, vertical to the ship itself, B being *inverted*, and C *erect*, having their hulls joined. As the ship receded from the shore, less and less of its mast became visible; and as it *descended*, the images B and C *ascended*; but as the ship did not recede below the horizon, Dr. Vince did not observe at what time, and in what order, the images vanished.

He then directed his telescope to another ship A,



whose hull was just in the horizon *x y*, and he observed a complete inverted image B, the mainmast of which just touched that of the ship itself. In this case there was no second image as before. While the ship A moved along, B followed its motion, without any change of appearance.

Dr. Vince observed a number of other ships, which produced variously formed images; but our limits will not permit us to give a particular description of them, nor of similar appearances which have been observed on various occasions at *land*.*

We shall, however, notice a few of the experiments made by Dr. Wollaston, to illustrate his theory of the cause of unusual refraction.

According to this ingenious philoshpher, the *varying density* of the atmosphere is the principal cause of the singular appearances which we have just mentioned; and from a number of interesting experiments, he found, that the results were perfectly conformable to this hypothesis.

He took a square phial, and poured a small quantity of clear *syrup* into it, and above this an equal quantity of *water*, which gradually incorporated with the syrup, between the pure water and the pure syrup. The word *syrup* written on a card, and held behind the bottle, appeared erect through the pure syrup; but when seen through the visible medium of the syrup and water, it appeared inverted with an erect image above.

* This subject has been fully treated by Dr. Wollaston, in the Philosophical Transactions for 1810.

Dr. Wollaston then put nearly the same quantity of *rectified spirit of wine* above the water, and he observed a similar appearance; only in this case, the true place of the object was seen uppermost, and the inverted and erect images below.

When the variations of density are great, the object may be held close to the phial; but when they become more gradual, the object is only elongated, and in order to be seen inverted, must be held one or two inches behind the phial.

By examining an oblique line seen in this way, he found, that the appearances continue many hours even with *spirit of wine;* with *syrup*, two or three days; with *sulphuric acid*, four or five; and still longer with a solution of *gum-arabic*.

Dr. Wollaston next heated a poker red hot, and looked along the side of it at a paper ten or twelve feet distant. A perceptible refraction took place at the distance of three-eighths of an inch from it. A letter, more than three-eighths of an inch distant, appeared erect as usual; at a less distance there was a faint reversed image of it; and still nearer the poker was a second image erect.

Although the experimental method of illustrating the phenomena of unusual refraction, as given by Dr. Wollaston, is in every respect an excellent one, yet the employment of different fluids does not represent the case which actually exists in nature.

The method employed by Dr. Brewster seems more agreeable to nature.

His method consists in holding a *heated iron* above a mass of water, bounded by parallel plates of glass.

As the heat descends through the fluid, a regular variation of density is produced, which gradually increases from the surface to the bottom.

If the heated iron be withdrawn, and a cold body substituted in its place, or even the air allowed to act alone, the superficial strata of water will give out their heat so as to have an increase of density from the surface to a certain depth below it. Through the medium thus constituted, all the phenomena of *unusual refraction* may be seen in the most beautiful manner; the variation of density being produced by heat alone.

OF THE CLOUDS.

Ye mists and exhalations that now rise
From hill or steaming lake, dusky or gray,
Till the sun paint your fleecy skirts with gold,
In honour to the world's Great Author rise,
Whether to deck with clouds th' uncoloured sky,
Or wash the thirsty earth with falling showers,
Rising or falling, still advance his praise. MILTON.

Clouds are generally supposed to consist of vapour which has been raised from the sea and land by means of heat. These vapours ascend till they reach air of the same specific gravity with themselves,

when they combine with each other, become more dense and opaque, and then become visible.

The thinner or rarer the clouds are, the higher do they ascend in the air; however, it seldom happens that their height exceeds two miles. The greater number of clouds are suspended at the height of one mile; and when they are highly electrified, their height is not above eight or nine hundred yards.

While Don Ulloa was in South America, measuring a degree of the meridian, he was for some time stationed on the summit of Cotapaxi, a mountain about three miles above the level of the sea, where he says—the clouds could be seen at a great distance below, and that he could hear the horrid noise of the thunder and tempests, and even see the lightnings issue from the clouds far below him.

The wonderful variety observable in the colours of clouds is owing to their particular position with respect to the sun, and the different reflections of his light. The various figures which they so readily assume, is supposed to proceed from their loose and voluble texture, revolving in any form, according to the direction and force of the wind, or to the quantity of electric matter which they contain.

> Sometime we see a cloud that's dragonish;
> A vapour, sometime, like a bear or lion,
> A towered citadel, a pendent rock,
> A forked mountain, a blue promontory,
> With trees upon't that nod unto the world,
> And mock our eyes with air.—
> That which is now a horse, even with a thought,
> The rock dislimns, and makes it indistinct
> As water is in water. SHAKSPEARE.

About the tropics the clouds roll themselves into enormous masses, as white as snow, turning their borders into the forms of hills, piling themselves upon each other, and exhibiting the shapes of mountains, caverns, and rocks. "There," says St. Pierre, "may be perceived amid endless ridges, a multitude of valleys, whose openings are distinguished by purple and vermillion." These celestial valleys exhibit, in their various colours, matchless tints of white, melting into shades of different colours. Here and there may be observed torrents of light issuing from the dark sides of the mountains, and pouring their streams, like ingots of gold and silver, over rocks of coral. These appearances are not more to be admired for their beauty than for their endless combinations, for they vary every instant. What, a moment before, was luminous, becomes coloured; what was coloured, mingles into shade; forming singular and most beautiful representations of islands and hamlets, arched bridges stretched over wide rivers, immense ruins, huge rocks, and gigantic mountains.

Among the Highlands of Scotland the clouds also display the finest outlines, and assume the most beautiful figures; more especially when viewed from their rugged and lofty summits. These bold and magnificent scenes are finely described by Dr. Beattie in the following lines:—

Oft when the wintry storm had ceased to rave,
He roamed the snowy waste at even, to view
The clouds stupendous, from the Atlantic wave
High lowering, sail along the horizon blue;
Where, 'midst the changeful scenery, ever new,
Fancy a thousand wondrous forms descries,
More wildly great, than ever pencil drew;
Rocks, torrents, gulfs, and shapes of giant size,
And glitt'ring cliffs on cliffs and fiery ramparts rise.

Minstrel.

"Clouds," says Dr. Thompson, "are not formed in all parts of the horizon at once: the formation begins in one particular spot, while the rest of the air remains clear as before; and though the greatest quantity of vapour exists in the lower strata of the atmosphere, clouds never begin to form there, but always at some considerable height." It is remarkable, says the same author, that the part of the atmosphere at which they form has not arrived at the point of extreme moisture, nor near that point, even a moment before their formation.

They are not formed, then, because a greater quantity of vapour has got into the air than could remain there without passing its maximum. It is still more remarkable, that when clouds are formed, the temperature of the spot does not *always* suffer a diminution, although this may sometimes be the case. On the contrary, the heat of the clouds themselves is sometimes greater than that of the surrounding air. Neither, then, is the formation of the clouds owing to the capacity of air for combining with moisture being lessened by cold. So far from this being the case, we often see clouds, which had remained in the atmosphere during the heat of the day, disappear in the night, after the heat of the air was diminished.

The formation of clouds and rain, then, cannot be accounted for by the principles with which we are acquainted. It is neither to the saturation of the atmosphere, nor the diminution of heat, nor the mixture of airs of different temperatures, as Dr. Hutton supposed; for clouds are often formed without any wind at all either above or below them: and even if this mixture constantly took place, the precipitation, instead of accounting for rain, would be almost imperceptible.

It is a well-known fact, that evaporation goes on for a month or two together in hot weather without any rain. This sometimes happens in the temperate zone; and every year in the torrid zone. At Calcutta, during the month of January, in the year 1785, it never rained at all: the mean of the thermometer for the whole month was 66½ degrees: there were no high winds, and, during the greater part of the month, scarcely any wind at all.

As the moisture which is thus raised by evaporation is not accumulated in the atmosphere, above the place from which it was evaporated, it must be disposed of in some other way; but the manner in which this is accomplished is not so well *known*. If it be carried on daily through the different strata of the atmosphere, and wafted to other regions by superior currents of air, it is impossible to account for the different electrical states of the clouds, situated between different strata, which often produce the most violent thunder storms.

For vapours are conductors of the electric fluid, and, of course, would daily restore the equilibrium of the whole atmosphere through which they passed. There would, therefore, be no positive and negative clouds, and consequently no thunder storms. Clouds could not have remained in the lower strata of the atmosphere and been daily carried off by winds to other countries; for there are often no winds at all, during several days, to perform this office; nor would the dews diminish as they are found to do when the dry weather continues for a long time.

It is impossible for us to account for this remarkable fact upon any principle with which we are acquainted. The water can neither remain in the atmosphere, nor pass through it in the state of vapour. It must, therefore, assume some other form; but what that form is, or how it assumes it, we do not know.

In order to render the study of meteorology more systematic, Mr. Luke Haward has lately introduced a scientific nomenclator for distinguishing the various forms or modifications of clouds, which promises to be of great use in this important, but hitherto neglected, branch of physical science.

The simple forms, or modifications, are three in number, and named, *Cirrus*, *Cumulus*, and *Stratus*. These are defined by Mr. Haward as follows:—The *Cirrus* is composed of parallel, flexuous, or diverging fibres, extensible in any or in all directions.

The *Cumulus*, convex or conical, heaps, increasing upwards from a horizontal base.

The *Stratus*, is a widely extended, continuous, horizontal sheet, increasing from below.

The intermediate modifications are four in number, each of which is formed from various combinations of the simple modifications just mentioned. They are the *Cirro-cumulus*, the *Cirro-stratus*, the *Cumulo-stratus*, and the *Cumulo-cirro-stratus*, or *Nimbus;* and are defined as follows.

Cirro-cumulus. Small well-defined roundish masses, in close horizontal arrangement.

Cirro-stratus. Horizontal or slightly-inclined masses, bent downward, or undulated, separate, or in groups consisting of a number of small clouds.

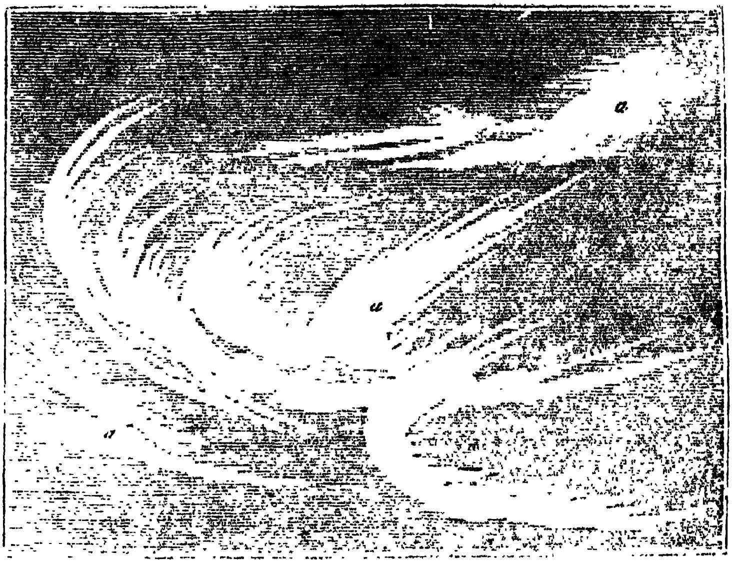
Cumulo-stratus. The cirro-stratus blended with the cumulus, and either appearing intermixed with the heaps of the latter, or superadding a wide-spread structure to its base.

Cumulo-cirro-stratus. The rain cloud. A cloud, or system of clouds, from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally, and from beneath.

OF THE CIRRUS.

Clouds in this modification appear to have the least density, the greatest elevation, and the greatest variety of extent and direction. They are the earliest appearance after serene weather. They are first indicated by a few threads pencilled, as it were, on the sky.

These increase in length, and new ones are in the mean time added laterally. Often the first-formed threads serve as stems to support numerous branches, which in their turn give rise to others. This modification is represented by the following figure.



The increase is sometimes perfectly indeterminate, at others it has a very decided direction. Thus the first few threads being once formed, the remainder shall be propagated either in one, two, or more directions laterally, or obliquely upward or downward, the direction being often the same in a great number of clouds visible at the same time.

Their duration is uncertain, varying from a few minutes after the first appearance to an extent of many hours. It is long when they appear alone and at great heights, and shorter when they are formed lower and in the vicinity of other clouds.

This modification, although in appearance almost motionless, is intimately connected with the variable motions of the atmosphere. Considering that clouds of this kind have long been deemed a prognostic of wind, it is extraordinary that the nature of this connection should not have been more studied, as the knowledge of it might have been productive of useful results.

In fair weather, with light variable breezes, the sky is seldom quite clear of small groups of the oblique cirrus, which frequently come on from the leeward, and the direction of their increase is to windward. Continued wet weather is attended with horizontal sheets of this cloud, which subside quickly and pass to the cirro-stratus.

Before storms they appear lower and denser, and usually in the

quarter opposite to that from which the storm arises. Steady high winds are also preceded and attended by streaks running quite across the sky in the direction they blow in.

The relations of this modification with the state of the barometer, thermometer, hygrometer, and electrometer, have not yet been attended to.

OF THE CUMULUS.

Clouds in this modification are commonly of the most dense structure: they are formed in the lower atmosphere, and move along with the current which is next the earth.

A small irregular spot first appears, and is, as it were, the nucleus on which they increase. The lower surface continues irregularly plane, while the upper rises into conical or hemispherical heaps; which may afterwards continue long nearly of the same bulk, or rapidly rise to mountains, as represented by the following figure.

In the former case they are usually numerous and near together, in the latter few and distant; but whether there are few or many, their bases always lie nearly in one horizontal plane, and their increase upward is somewhat proportionate to the extent of base, and nearly alike in many that appear at once.

Their appearance, increase, and disappearance, in fair weather, are often periodical, and keep pace with the temperature of the day. Thus they will begin to form some hours after sun-rise, arrive at their maximum in the hottest part of the afternoon, then go on diminishing, and totally disperse about sun-set.

But in changable weather they partake of the vicissitudes of the atmosphere; sometimes evaporating almost as soon as formed, at others suddenly forming and as quickly passing to the compound modifications.

The cumulus of fair weather has a moderate elevation and extent, and a well defined rounded surface. Previous to rain it increases more rapidly, appears lower in the atmosphere, and with its surface full of loose fleeces or protuberances.

Independently of the beauty and magnificence it adds to the face of nature, the cumulus serves to screen the earth from the direct rays of the sun, by its multiplied reflections to diffuse, and, as it were, economise the light, and also to convey the product of evaporation to a distance from the place of its origin. The relations of the cumulus with the state of the barometer, &c. have not yet been sufficiently attended to.

The formation of large cumuli to leeward in a strong wind, indicates the approach of a calm with rain. When they do not disappear or subside about sun-set, but continue to rise, thunder is to be expected in the night.

OF THE STRATUS

This modification has a mean degree of density.

It is the lowest of clouds, since its inferior surface commonly rests on the earth or water, as represented by the following figure.

Contrary to the last, which may be considered as belonging to the day, this is properly the cloud of night; the time of its first appearance being about sun-set. It comprehends all those creeping mists which in calm evenings ascend in spreading sheets (like an inundation of water) from the bottom of valleys and the surface of lakes, rivers, &c.

Its duration is frequently through the night.

On the return of the sun the level surface of this cloud begins to put on the appearance of cumulus, the whole at the same time separating from the ground. The continuity is next destroyed, and the cloud ascends and evaporates, or passes off with the appearance of the nascent cumulus.

This has been long experienced as a prognostic of fair weather, and indeed there is none more serene than that which is ushered in by it. The relation of the stratus to the state of the atmosphere as indicated by the barometer, &c. appears notwithstanding to have passed hitherto without much attention.

OF THE CIRRO-CUMULUS.

The cirrus having continued for some time increasing or stationary, usually passes either to the cirro-cumulus or the cirro-stratus, at the same time descending to a lower station in the atmosphere.

The cirro-cumulus is formed from a cirrus, or from a number of small separate cirri, by the fibres collapsing as it were, and passing into small roundish masses, in which the texture of the cirrus is no longer discernible, although they still retain somewhat of the same relative arrangement, as exhibited by the following figure.

This change takes place either throughout the whole mass at once, or progressively from one extremity to the other. In either case, the same effect is produced on a number or adjacent cirri at the same time and in the same order. It appears in some instances to be accelerated by the approach of other clouds.

This modification forms a very beautiful sky, sometimes exhibiting numerous distinct beds of these small connected clouds, floating at different altitudes.

The cirro-cumulus is frequent in summer, and is attendant on warm and dry weather. It is also occasionally and more sparingly seen in the intervals of showers, and in winter. The following passage is beautifully descriptive of the appearance of this modification by moonlight:

> For yet above these wafted clouds are seen
> (In a remoter sky, still more serene,)
> Others, detached in ranges through the air,
> Spotless as snow, and countless as they're fair;
> Scatter'd immensely wide from east to west,
> The beauteous semblance of a flock at rest.
> These to the raptur'd mind aloud proclaim
> Their mighty shepherd's everlasting name. BLOOMFIELD.

It may either evaporate or pass to the cirrus or cirro-stratus.

OF THE CIRRO-STRATUS.

This cloud appears to result from the subsidence of the fibres of the cirrus to a horizontal position, at the same time that they approach towards each other laterally. The form and relative position, when seen in the distance, frequently give the idea of shoals of fish. Yet in this, as in other instances, the structure must be attended to rather than the form, which varies much, presenting at other times the appearance of parallel bars, interwoven streaks like the grain of polished wood, &c. It is always thickest in the middle, or at one extremity, and extenuated towards the edge, as represented by the following figure.

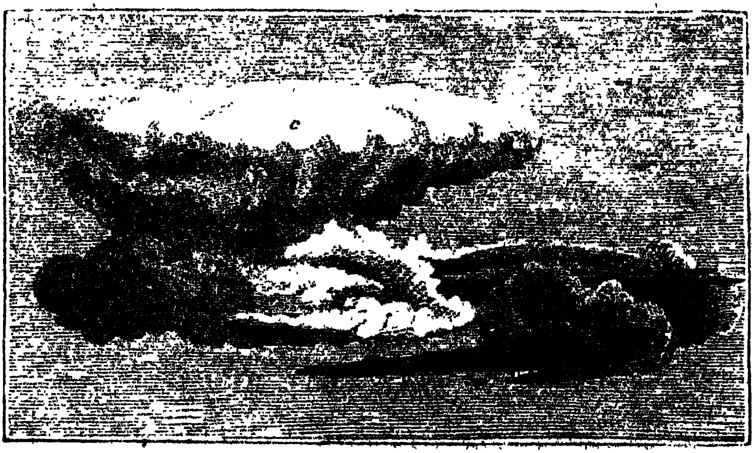
The distinct appearance of a cirrus does not always precede the production of this and the last modification.

The cirro-stratus precedes wind and rain, the near or distant approach of which may sometimes be estimated from its greater or less abundance and permanence. It is almost always to be seen in the intervals of storms. Sometimes this and the cirro-cumulus appear together in the sky, and even alternate with each other in the same cloud, when the different evolutions which ensue are a curious spectacle, and a judgment may be formed of the weather likely to ensue by observing which modification prevails at last. The cirro-stratus is the modification which most frequently and completely exhibits the phenomena of the solar and lunar halo, and (as supposed from a few observations) the parhelion and paraselene also. Hence the reason of the prognostic for foul weather, commonly drawn from the appearance of the halo.

OF THE CUMULO-STRATUS.

The different modifications which have been just treated of sometimes gives place to each other, at other times two or more appear in

the same sky; but in this case the clouds in the same modification lie mostly in the same plane of elevation, those which are more elevated appearing through the intervals of the lower, or the latter showing dark against the lighter ones above them. When the cumulus increases rapidly, a cirro-stratus is frequently seen to form around its summit, reposing thereon as on a mountain, while the former cloud continues discernible in some degree through it. This state continues but a short time. The cirro-stratus speedily becomes denser and spreads, while the superior part of the cumulus extends itself and passes into it, the base continuing as before, and the convex protuberances changing their position till they present themselves laterally and downward. These are well represented by the following figure.



More rarely the cumulus alone performs this evolution, and its superior part constitutes the incumbent cirro-stratus.

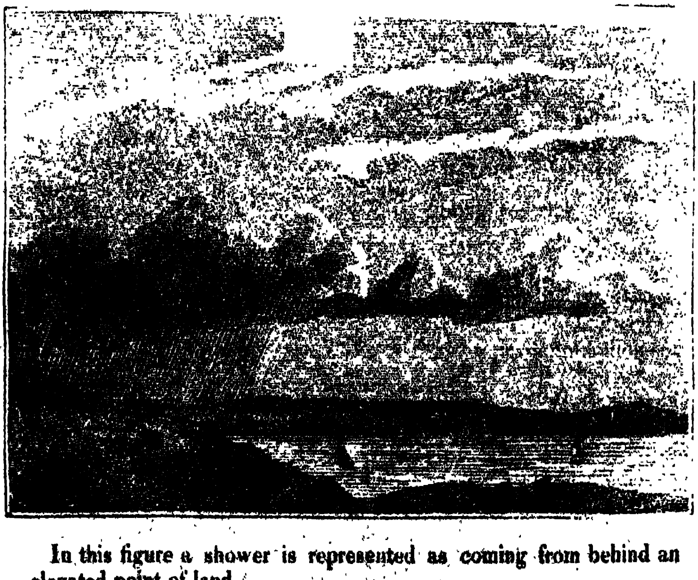
In either case a large lofty dense cloud is formed, which may be compared to a mushroom with a very thick short stem. But when a whole sky is crowded with this modification, the appearances are more indistinct. The cumulus rises through the interstices of the superior clouds, and the whole, seen as it passes off in the distant horizon, presents to the fancy mountains covered with snow, intersected with darker ridges and lakes of water, rocks and towers, &c. The distinct cumulo-stratus is formed in the interval between the first appearance of the fleecy cumulus and the commencement of rain, while the lower atmosphere is yet too dry; also during the approach of thunder storms: the indistinct appearance of it is chiefly in the longer or shorter intervals of showers of rain, snow, or hail.

The cumulo-stratus chiefly affects a mean state of the atmosphere as to pressure and temperature; but in this respect, like the other modifications, it affords much room for future observation.

OF THE NIMBUS, OR CUMULO-CIRRO-STRATUS.

Clouds in any one of the preceding modifications, at the same degree of elevation, or in two or more of them, at different elevations, may increase so as completely to obscure the sky, and at times put on an appearance of density which to the inexperienced observer indicates the speedy commencement of rain. It is nevertheless extremely probable, as well from attentive observation as from a consideration of the several modes of their production, that the clouds, while in any one of these states, do not at any time let fall rain.

Before this effect takes place they have been uniformly found to undergo a change, attended with appearances sufficiently remarkable to constitute a distinct modification, which is represented by the following figure, called the Nimbus, or Cumulo-cirro-stratus cloud.



In this figure a shower is represented as coming from behind an elevated point of land.

The nimbus, although in itself one of the least beautiful clouds, is yet now and then superbly decorated with its attendant the rainbow; which can only be seen in perfection when backed by the widely extended uniform gloom of this modification.

The relations of rain, and of periodical showers more especially, with the varying temperature, density, and electricity of the atmosphere, will probably now obtain a fuller investigation, and with a better prospect of success, than heretofore.

MOTIONS OF THE EARTH.

She from the *West* her silent course advances
With inoffensive pace, that spinning sleeps
On her soft axle; while she paces even,
And bears us soft with the smooth air along.

MILTON.

When we consider the apparent diurnal motion of all the celestial bodies, we cannot but recognise the existence of one general cause, which produces this appearance. But when we consider that these bodies are not only at different distances from the earth, but at different distances from each other, and that these distances are not always the same, we shall find it difficult to conceive that it is the same cause that produces this appearance on all of them.

The difficulty, however, becomes considerably less when it is recollected, that a person in motion, looking at an object at rest, perceives the same change of position in the object as if he were himself at rest, and the object in motion in the opposite direction. Every one who has looked, for the first time, from the window of a carriage moving quickly along the road; or from the deck of a ship sailing smoothly along the shore; fancies that every thing which the carriage or vessel passes is in motion, and that he is himself at rest.

An appearance still more deceiving takes place, when a person looks out of the cabin window of a ship, in a dark night, at a distant light apparently in motion. For the change of place in the light may arise either from its being really in motion, or on board of another vessel, while the vessel in which the spectator is placed is at anchor; or the light may be stationary, and its apparent motion occasioned by the motion of the ship which carries the spectator; or it may even be occasioned by the motion of the vessel which carries the light being quicker or slower than the one which carries the spectator. The difficulty in determining to which of these causes the motion of the light is to be attributed, arises from the want of some intervening object whose state is known, and by which the apparent motion may be compared. Now this is precisely the situation in which we stand with regard to the heavenly bodies. For the motion of the earth on its axis, if it really has such a motion, must be incomparably smoother than any vessel or machine made by human art; and as there is no fixed intermediate object between it and the heavenly bodies, no direct proof of this motion can be obtained.

As far, then, as appearances enable us to judge, either the earth may be at rest, and the heavens carried round it every twenty-four hours, or the heavens may be at rest, and the earth revolve round its axis, in the same time. For the rising and setting of the sun and stars, with all the other celestial phenomena, will be presented in the same order whether the heavens revolve round the earth, or the earth round its axis.

However, on comparing these appearances with others which are more within our reach, and with the established laws of motion, we

shall find it is much more probable they are occasioned by the revolution of the earth on its axis, than the revolution of the whole heavens. For as the heavenly bodies present the same appearances to us, whether the firmament carries them round the earth, or the earth itself revolves in a contrary direction, it seems much more natural to admit the latter hypothesis than the former, and to regard the motion of the heavens as only apparent.

The semidiameter of the earth is only about 4000 miles, and consequently its circumference is about 25,000 miles.

This is, therefore, the space every point of its equator must pass through, if the earth revolves on its axis, which is little more than 1000 miles per hour, or about 17 miles per minute. This velocity is certainly very considerable, being nearly equal to that of a cannon-ball when it leaves the mouth of a cannon; but it becomes totally insignificant when compared with the motion of some of the heavenly bodies, required on the other supposition. The distance of the sun from the earth is about ninety-five millions of miles;* and therefore if he revolves round the earth in twenty-four hours, he must pass over more than six times this space in the same time, and consequently must move at the rate of about 25,000,000 miles per hour, which is more than 20,000 times quicker than a cannon-ball. The planet Uranus is about twenty times farther distant from the earth than the sun, and consequently the velocity of its daily motion must be twenty times greater.† But although these velocities are sufficient to startle the imagination, they are really nothing when compared to the rapidity with which the fixed stars must move to accomplish a revolution round the earth in twenty-four hours. If the distance of the fixed stars be assumed at 200,000 times the distance of the sun from the earth,‡ they must move over the space of 1,400,000,000 miles per second, in order to complete a revolution round the earth in twenty four hours! This is a degree of velocity of which we can have no kind of conception; and yet, if we consider the velocity which those stars must have that are many thousands of times more distant from the earth, it must be almost infinitely greater. If we, therefore, take into consideration the number of bodies that must move, and the prodigious rapidity of their motions, to produce the same appearances which the revolution of one body, with a comparatively moderate velocity, can produce, we shall scarcely hesitate a moment in concluding that the motion of this one body is the true cause of these appearances.

This conclusion must appear still more obvious when we attend to the comparative bulk of these different bodies. Of the planets which belong to the solar system, three of them are known to be much greater than the earth; Jupiter being nearly fifteen hundred times: Saturn nine hundred times; and Uranus eighty times. But the sun exceeds them all in magnitude, being considerably more than a million of times greater than the earth. Our ignorance of the real distances of the fixed stars prevents us from ascertaining correctly their

* See page 26. † Page 40. ‡ Page 33.

real magnitudes; but, from what we know of their distances, we are entitled to conclude that they are at least equal in size to the largest of the planets. If such, therefore, be the magnitude of these bodies, how inconsistent would it be with every idea of order and arrangement to suppose, that such a vast number of immense bodies daily revolve round such a little and comparatively insignificant body as the earth! What extraordinary power would be necessary to retain them in their orbits, and counterbalance the amazing centrifugal force which they must possess! The idea, too, of so many immense and independent bodies, so vastly distant from the earth and from each other, performing their revolutions round this little ball, exactly in the same number of seconds, is scarcely to be entertained for a single moment: all the phenomena, especially when supposed to arise from these revolutions, can be satisfactorily and easily accounted for, by supposing the earth to revolve on its axis.

If we suppose the planets to be carried round the earth, from east to west, every twenty-four hours, and also allow them a motion peculiar to themselves from west to east (which they are observed to have), we produce such a combination of opposite motions, as has never yet been observed in any of the heavenly bodies, and which it would be impossible to reconcile with any of the known principles of mechanics. But the rotation of a body on its axis, combined with a motion in its curvilineal orbit, is what we are quite familiar with, and what is exhibited by a school-boy by spinning his top.

But one of the strongest proofs of the rotation of the earth is its figure. For it is now well known that the earth is not a perfect sphere; its polar diameter being considerably less than its equatorial.* It is also known that this is the shape which a spherical body would in time assume, if it revolved on a fixed axis; and therefore it is reasonable to conclude that the spheroidical figure of the earth is occasioned by its rotatory motion. This conclusion is supported by the extraordinary fact, that the difference between the polar and equatorial axis of the earth, as deduced from theory alone, is nearly the same as from actual measurement of various arcs of meridian circles. —The same conclusion is farther supported by analogy.

A rotatory motion has been observed in several of the other planets, and from west to east, the direction in which the earth must revolve in order to occasion the apparent diurnal motion of the heavens from east to west. Jupiter, a much larger body than the earth, turns round his axis in less than twelve hours. Now both the earth and Jupiter are known to be flattened at the poles. All these facts, therefore, lead us to conclude that the earth has really a motion of rotation, and that the diurnal motion of the heavens is only an illusion produced by this rotation.

The diurnal rotation of the earth being assented to, its annual motion will scarcely be denied; for its similarity to the other planets

* Some of the objections which have been stated against the rotation of the earth will be noticed in treating of the Ptolemaic and Tychonic systems.

is considerably strengthened by this circumstance. For the planets being found to revolve on their axis, and to be flattened at the poles like the earth; and being found to have periodical revolutions from west to east, we are led to suppose, that the earth has a *similar* revolution, in order to render the analogy between it and the rest of the planets complete. But the appearances afford us as little assistance in ascertaining the truth of this supposition, as in the case of the diurnal motion; for whether we suppose the earth to be at rest and the sun to move round it in the ecliptic in the course of a year, or the sun to be at rest and the earth to describe this path in the same time; the phenomena of the seasons, eclipses, and all other appearances connected with the sun's annual motion, may be explained on either hypothesis. But, although this be the case, it is much more probable that these appearances are produced by the annual motion of the earth round the sun, than by the motion of the sun round the earth. For by supposing the earth to move round the sun, we not only give order and simplicity to the solar system, and preserve the analogy, which is so conspicuous among the other bodies which compose that system, but we remove several difficulties which unavoidably attend the opposite hypothesis.—It has already been remarked, that the earth is considerably smaller than several of the other planets, and that it is about fourteen hundred thousand times less than the sun; it is therefore quite inconsistent with every idea of order and arrangement to suppose, that bodies of such extraordinary size should revolve round one of comparatively small magnitude. For, independent of the complication of the planetary motions which such a supposition would introduce, it would overthrow one of the best established principles of mechanics and is quite inconsistent with the law which is known to subsist between the times of the revolutions of the planets, and their distance from the sun. For the farther they are from the sun, their motion is the slower. Their periodic times of revolution being to each other as the cubes of their mean distances from the sun. Now according to this remarkable law, the length of a revolution of the earth round the sun, should be exactly a sidereal year. This is therefore an incontestible proof that the earth moves round the sun, like the other planets, and is subject to the same laws. To this we may add, that the aspects of increase and decrease of the planets, the times of their seeming to stand still, and move direct and retrograde, answer precisely with the motion of the earth: but cannot be reconciled with that of the sun, without introducing the most absurd and monstrous suppositions, which would destroy all order, harmony, and simplicity, in the system.

But the most direct proof of the earth's annual motion is derived from the aberration of light. For during the time which light takes to pass over the semidiameter of the earth's orbit, which is 8′ 13″, the earth ought to move 20″·232 in its orbit, and this is found by observations to be actually the case.

The annual as well as the diurnal motion of the earth may therefore be considered as completely established. The objections which have been urged against these motions, by the supporters of the Ptolemaic and Tychonic systems of the heavens, will be noticed when treating of these systems.

To the texts of Scripture which seem to contradict the motion of the earth, the following reply may be made to them all,—That it is plain from many instances, that the Scriptures were never designed to instruct men in philosophy, but in matters of religion, and are not always to be taken in the literal sense. For Job describes the earth as being *supported* upon *pillars*, and in another place as being hung upon *nothing;* and Moses calls the moon a great luminary, although it is well known to be an *opaque* body, which shines only by reflecting the light of the sun.

It is perfectly certain these expressions were not meant to convey any astronomical opinion; but employed because they would be easily understood by those to whom they were immediately addressed. In familiar discourse, astronomers themselves speak of the sun's place in the ecliptic, of his rising and setting, &c.; for if they did not, they would be under the necessity of explaining their meaning every time they had occasion to mention those appearances to those who knew nothing of astronomy.

The poet Thomson, though perfectly well convinced of the annual motion of the earth, says—

> At last from Aries rolls the bounteous sun,
> And the bright Bull receives him.

And Baker, in his elegant and truly philosophical poem, entitled the "Universe," says—

> Along the skies the sun obliquely rolls,
> Forsakes, by turns, and visits both the poles.
> Diff'rent his tract, but constant his career,
> Divides the times, and measures out the year.
> To climes returns where freezing winter reigns,
> Unbinds the glebe, and fructifies the plains;
> The crackling ice dissolves; the rivers flow;
> Vines crown the mountain-tops, and corn the vales below.
>
> BAKER.

ON THE CHANGE OF SEASONS.*

At one wide view God's eye surveys
His works in every distant clime;
He shifts the seasons, months, and days,
The short-lived offspring of revolving time;
By turns they die, by turns are born.
Now cheerful Spring the circle leads,
And strews with flowers the smiling meads;
Gay Summer next, whom russet robes adorn,
And waving fields of yellow corn;
Then Autumn, who with lavish stores the lap of Nature spreads.
Decrepid Winter, laggard in the dance,
(Like feeble age opprest with pain)
A heavy season does maintain,
With driving snows, and winds, and rain,
Till Spring, recruited to advance,
The various years rolls round again.

HUGHES.

The earth's rotation makes the night and day;
The sun revolving through th' ecliptic way,
Effects the various seasons of the year. BLACKMORE.

The alternate succession of day and night, as well as the variety of seasons, depend entirely on the motions of the earth. For if the sun and the earth were perfectly at rest with respect to each other, it is evident that one half of the earth would always be in the light, and the other half in darkness, as the sun can only enlighten one half of its surface at a time. But as the earth turns round its axis once in twenty-four hours, any particular place on its surface will pass through light and darkness alternately. As long as it continues in the enlightened hemisphere, it will be day at that place; but while it passes through the opposite hemisphere, it will be night. But although the regular succession of day and night be occasioned by the diurnal revolution of the earth on its axis, yet this motion is not of itself sufficient to produce that variety in the lengths of days and nights, which the various places of the earth experience in the course of a year.

For should it revolve on its axis, with one of its poles always pointed exactly to the sun, one half of the earth would be constantly in the light and the other half in darkness, notwithstanding its rotation. Again, if we suppose the earth to turn on its axis, with its equator directly pointed to the sun, then the light would just reach both poles, consequently all places would be in light and darkness alternately, and the days and nights would be exactly twelve hours each at every part of the globe.

If either extremities of the earth's axis, suppose the northern, were to make an acute angle with an imaginary line joining the centre of

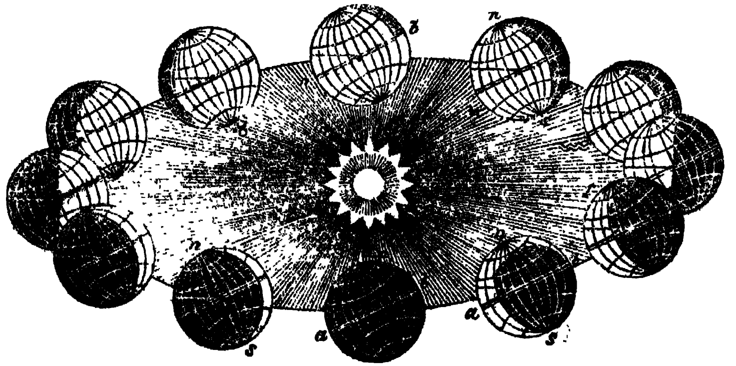
* If a terrestrial globe be placed in the various positions mentioned in this article, it will contribute very much to impress the mind with the true cause of the change of the seasons.

the sun with any point of the earth's equator, it would follow that the north pole, and a certain tract round it, would remain always in the light, notwithstanding the revolution of the earth on its axis. Even those places in the northern hemisphere to which the sun appeared to rise and set, would have their days always longer than their nights; at the equator the days and nights would be equal; but in the southern hemisphere the reverse would happen to what took place in the northern. For those places to which the sun appeared to rise and set would have their nights longer than their days; and the south pole would be constantly in darkness, with a tract around it equal to what was constantly in the light round the north pole. It is evident, also, that in this case the sun would be always on the north side of the equator, and vertical to a certain circle parallel to it, which would be as many degrees from the equator as the angle contained between the earth's axis and the imaginary line wanted of a right angle.

This last supposition is in some degree similar to what actually takes place in nature; for the axis of the earth makes an angle of 23½ degrees, with a perpendicular to its orbit; and as the axis always remains parallel to itself, or points in the same direction, this angle must be constantly changing as the earth moves forward in its orbit.*

> Some say he bid his angels turn askance
> The poles of earth twice ten degrees and more
> From the sun's axle; they with labour push'd
> Oblique the central globe. MILTON.

This is well represented by the following figure, which shews the earth in twelve different positions, or at twelve different times of the year.



The line *a b* is the equator, *n* the north pole, and *s* the south. The signs of ♐, ♒, &c. denote the points of the ecliptic in which the earth is when it has the positions in the figure.

* Or, what amounts to the same thing, the axis of the earth makes an angle with the plane of the ecliptic of 66½ degrees.

As the position of the poles of the earth, with respect to the sun, depends entirely on this angle, their position must always be changing; and, of course, every point on the earth's surface must also alter its position with respect to the sun. About the 20th of March, when the sun, as seen from the earth, enters the sign Aries, the line supposed to join the centres of the earth and sun is perpendicular to the earth's axis; consequently both poles are similarly situated with respect to the sun, as he is then directly over the equator, and the days and nights are equal at every place on the globe. This time of the year is called the *vernal equinox*, because spring commences to the inhabitants of the northern hemisphere, while autumn begins to those of the southern.

After the 20th of March the sun appears to rise every day sensibly more to the northward than he did the day before, to be more elevated at mid-day, and to continue longer above the horizon, till the 21st of June, which is the longest day at all places in the northern hemisphere. At this time the angle formed by the northern half of the earth's axis and the line joining the centre of the earth and sun is then at the least, which is $66\frac{1}{2}$ degrees. The sun will then appear to touch the tropic of Cancer, and be vertical to all places $23\frac{1}{2}$ degrees north of the equator. This time of the year is called the *summer solstice*, because it is the middle of summer, and the sun seems to remain stationary for a few days.

After the 21st of June, the angle joining the centres of the earth and sun gradually increases, and the sun appears to recede from the tropic of Cancer, in the same manner as he advanced to it, rising every day a little farther to the south than he did the day before, till the 23 of September, when the axis has a similar position to what it had on the 20th of March, being again at right angles to the line just mentioned, consequently the days and nights are again equal all over the globe, which constitutes the *autumnal equinox*.

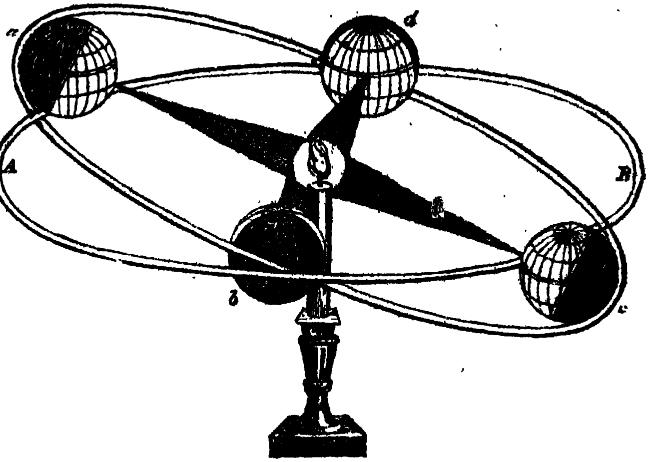
The sun now appears to cross the equinoctial, and the south pole, which, during the last six months, was in the dark, begins to turn towards the sun; and precisely the same phenomena are exhibited to the southern hemisphere as those already described in the case of the northern half of the earth. On the 22d of December the sun appears to touch the tropic of Capricorn, and is vertical to all those places on the earth that are $23\frac{1}{2}$ degrees south of the equator. The days are then longest at all places in the southern hemisphere, but at the shortest in the northern. This time of the year is termed the *winter solstice*.

From the tropic of Capricorn the sun again appears to move forward, and to arrive at the equinoctial again on the 20th of March.

Thus by a combination of the *annual* and diurnal motions of the earth, with the parallelism of its axis, and the obliquity of its orbit to the plane of its equator, the various seasons are produced, and the same quantity of light and darkness, in the space of a year, are distributed to every region of the globe.

The manner in which the sun enlightens the earth, the parallelism of its axis, and the increase and decrease of the days and nights,

may be well illustrated by a small terrestrial globe, suspended by a string fastened to its north pole, as represented by the following figure.



A circle of wire *a b*, representing the plane of the earth's equator, may be held parallel to a table, and equal in height with the flame of a candle standing upon it. If the string be twisted a little towards the left hand, and the globe suspended within the circle, with its equator at the same height, the globe will begin to turn on its axis from west to east, and day and night will be represented by the light and shade produced by the candle on its surface. But if the globe be carried round the wire, to represent a year, the candle will illuminate both poles, and every spot on its surface will describe half a circle in the enlightened part, and half in the dark part, and make equality of day and night through the year. This is, however, not the case in nature, as has already been fully explained. If then the wire be inclined to the table at an angle of 23½ degrees, as represented by the circle *a b c d*, and the globe be carried gently round it, the seasons, and increase of day and night, will appear as they are in nature; i. e. when the globe is at *a*, the candle enlightens it no farther northward than the arctic circle *n o*; all within which, in the middle of our winter, is deprived of a sight of the sun; while all places within the antarctic, or opposite circle, have perpetual day: at this time the candle shines vertically on the tropic of Capricorn. As the earth moves towards *b* (the vernal equinox), if a small patch be laid on latitude 51½° north, it will shew how the days increase at London, and how the nights decrease. When it has arrived at *b*, the candle will then be perpendicularly over the equator, and, shining to both poles, equality of day and night will take place: as it proceeds towards *c* (the summer solstice), the days increase, and the candle shines more and more over the north pole: when it has arrived at *c*,

the whole arctic circle, and the countries it includes, will revolve in continual sight of the sun; and all within the antarctic circle will be deprived of that sight. At this time the candle shines vertically on the tropic of Cancer. Moving from midsummer towards *d* (the autumnal equinox), the days will be found to decrease, and the nights to increase in length, till they come again to equality at *d*, and thence to the winter solstice, and so on.

The particular temperature which distinguishes each of the seasons, at any particular place, is owing to a difference in the sun's altitude, and the time of his continuance above the horizon of that place. In winter, the rays of the sun fall so obliquely, and the sun is such a short time above the horizon, that his influence in heating the earth is but very little, compared with what it is in summer. For at this season, the sun is so much higher than in winter, that his rays not only fall more perpendicularly, but more of them fall on any given space; and as the day is also much longer than the night, the temperature of the earth and the surrounding atmosphere must be much greater than in winter.

Since the power of the sun is greater in heating the earth at any particular place, when his rays fall most directly, and when the days are longest at that place, it may be asked, how does it happen that the heat is greatest about the end of July, when the sun is highest and the day longest about the 21st of June? The reason of this may easily be discovered by attending a little to the manner in which bodies are heated. The heat which the earth receives is not transient, but is retained by it for some time. For, like other solid bodies, it receives heat and parts with it gradually. Now as the earth continues to receive more heat in the day than it gives out in the night, for a considerable time after the 21st of June, its temperature will continue to increase, till the days and nights begin to approach to an equality. But this is not the case till the end of July, at least; the earth goes on increasing in temperature, till about this time, when it is found to be much greater than about the 21st of June, although the sun be then higher at mid-day, and the day longer than at any other time of the year in the northern hemisphere.* The heat in July would be still greater were the sun at his mean distance from the earth; but this is not the case, for he is then at his greatest distance. However, the difference between his distance at this time and the mean distance being only $\frac{1}{61}$th part of the whole, it could not make a great alteration in the heating power of the rays. But if it does operate in any degree in diminishing the heat in the northern hemisphere in July, the same cause must operate in increasing the heat, but in a double degree, in the southern hemisphere in January. For the sun is $\frac{1}{61}$th part nearer the earth than his mean distance on the 1st of January. Consequently the heat must be greater in the southern hemisphere in January than in the northern in July, all other circumstances being the same. The effects of the direct in-

* The same phenomena take place in the southern hemisphere in a reverse order, or at six months' difference of time.

fluence of the sun are, however, greatly modified by the transportation of the temperature of one region into another, in consequence of that disturbance in the equilibrium of the atmosphere which the action of the sun's rays necessarily produce.

Thus we see by what simple means the whole variety of the seasons are produced; and also how admirably fitted the means are to accomplish the end.

These, as they change, Almighty Father, these
Are but the *varied* God. The rolling year
Is full of Thee. Forth in the pleasing Spring
Thy beauty walks, Thy tenderness and love.
Wide flush the fields; the softening air is balm;
Echo the mountains round; the forest smiles;
And every sense, and every heart is joy.
Then comes Thy glory in the Summer months,
With light and heat refulgent. Then Thy sun
Shoots full perfection through the swelling year:
And oft Thy voice in dreadful thunder speaks;
And oft at dawn, deep noon, or falling eve,
By brooks, and groves, in hollow-whispering gales.
Thy bounty shines in Autumn unconfin'd,
And spreads a common feast for all that lives.
In Winter awful Thou! with clouds and storms
Around Thee thrown, tempest o'er tempest roll'd,
Majestic darkness! on the whirlwind's wing,
Riding sublime! Thou bidst the world adore.

ON THE REGULATION OF TIME BY THE HEAVENLY BODIES.

Time of itself is nothing, but from thought
Receives its rise; by labouring fancy wrought
From things considered, while we think on some
As present, some as past, or yet to come.
No thought can think on time that's still confest,
But thinks on things in motion or at rest.

Though time, considered in an abstract and philosophical point of view, was certainly coeval with the Deity, since nothing can possibly exist but in some portion of it, yet the measuring of time is a matter of a very different nature; and though various nations have differed on this subject, it is, nevertheless, a subject of the utmost importance to every human being. For the opposite and contradictory methods of calculating time have often been productive of very great mischief in the world; while chronologers, sometimes from ignorance, and as often from prejudice, have misrepresented events, which, however trifling they might appear to them, may nevertheless affect the happiness of future ages. During the general *chaos*, or that period when the materials of which the beautiful fabric of the universe was what Ovid calls *rudis indigestaque moles*, a rude and indigested heap, there were no human beings, and consequently no occasion for any method of measuring or regulating time. But as

soon as the world was made a fit habitation for man, the measurement of time became necessary on many accounts; our pleasures as well as our interests, require that this object should be accomplished; but it is only an acquaintance with astronomy that can furnish the means of doing it correctly. For time has always been measured and defined by the motions of the heavenly bodies, and particularly by the sun, as being the most regular and constant in his apparent revolutions.*

The principal divisions of time are the year and the day, which are measured by the annual and diurnal revolution of the sun. The day, or the time in which the sun appears to go round the earth, has been divided into twenty-four equal parts, which are called hours, and these again subdivided into minutes, &c. This division is, however, merely arbitrary; there being no astronomical appearance to warrant or regulate such a division of the day, more than a division into twenty-two, forty-eight, or any other number of equal parts.

The length of the tropical year, or the time the sun is in going from any point of the ecliptic to the same again, is 365 days, 5 hours, 48 minutes, 49 seconds. But the sidereal year, or the time which intervenes between the conjunction of the sun and any fixed star and his next conjunction with the same star, is 365 days, 6 hours, 9 minutes, $11\frac{1}{2}$ seconds. The difference between these two periods, which amounts to $20' \, 22\frac{1}{2}''$, is occasioned by the recession of the equinoxes, or the falling back of the equinoctial points $50\frac{1}{4}$ seconds of a degree every year. This retrograde motion of the equinoctial points is caused by the joint attraction of the sun and moon upon the earth, in consequence of its spheroidical figure.†

Time is distinguished according to the manner of measuring the day, into *apparent*, *mean*, and *sidereal*. Apparent time, which is also called true, solar, and astronomical time, is derived from observations made on the sun. Mean, or mean solar time, sometimes called *equated time*, is a mean or average of apparent time, which is not always equal; for the intervals between two successive transits of the sun over the meridian are not always the same. This is owing to the eccentricity of the earth's orbit, and its obliquity to the plane of the equinoctial. If the earth's orbit were an exact circle, and coincident with the equinoctial, the sun would always return to the meridian of any place at equal intervals of time, and apparent and mean solar time would be the same. But as this is not the case, mean time is deduced from apparent by adding or subtracting the difference between them, which is usually called the equation of time.

Mean solar days are all equal, being twenty-four hours each; but apparent solar days are sometimes more than twenty-four hours, and

* As it may contribute to perspicuity in treating of this important subject, we shall consider the *apparent* motions of the sun as *real*.

† These variations are computed and inserted in a table, which is called a Table of the *Equation of Time*.

sometimes less. A sidereal day is the interval between two successive transits of a star over the same meridian, and is always of the same length; for all the fixed stars make their revolutions in equal times, owing to the uniformity of the earth's diurnal rotation about its axis. The sidereal day is however shorter than the mean solar day by 3′ 56$\frac{1}{3}$″. This difference arises from the sun's apparent annual motion from west to east, by which he leaves the star as it were behind him. Thus if the sun and a star be observed on any day to pass the meridian at the same instant, the next day, when the star passes the meridian, the sun will have advanced nearly a degree to the eastward; and, as the earth's diurnal rotation on its axis is from west to east, the star will come to the meridian before the sun, and in the course of a year the star will have gained a whole day on the sun, that is, it will have passed the meridian 366 times while the sun will only have passed it 365 times. Now as the sun appears to perform the whole of the ecliptic in 365 days, 5 hours, 48 minutes, 49 seconds, he describes 59′ 8 3″, or nearly one degree of it per day, at a mean rate; and this space reduced to time is exactly 3′ 56$\frac{1}{2}$″, the excess of a mean solar day above a sidereal day.*

The equation of time, or the difference between mean and apparent time, as already mentioned, arises from two causes; namely, the obliquity of the ecliptic to the plane of the equinoctial, and the eccentricity of the earth's orbit. There are, however, four days in the year when the equation of time is nothing, or when the mean and apparent time coincide; these days are, at present, the 15th of April, the 15th of June, the 1st of September, and the 24th of December. From the first of these days to the second, the *apparent* time is before the mean; from the second to the third, the *mean* time is before the apparent; from the third to the fourth, the apparent is before the mean; and from the last of those days to the first, the mean is again before the apparent, and so on alternately.†

If the revolution of the sun consisted of an entire number of days, for instance 365, the year would naturally be made to do the same, and there would be no difficulty in the formation of the *calendar*, or in adjusting the reckoning in years and in days to one another.

All the years would thus contain precisely the same number of days, and would also begin and end with the sun in the same point of the ecliptic. But the sun's revolution includes a fraction of a day, and therefore a year and a revolution of the sun cannot be precisely completed at the same moment. However, as this fraction makes a whole day in four revolutions, one day is added every four years, in order to make this number of years equal to the same number of revolutions. The year to which this day is added therefore contains 366 days.

This is the arrangement of what is called the *Julian Calendar*, and

* This excess is sometimes called the acceleration of the fixed stars.

† Clocks and watches ought to be regulated by mean time, as none of them can shew apparent time, because they are all constructed on the principle of uniform and equable motion.

the year thus computed, is termed the *Julian* year, from Julius Cæsar, by whom it was introduced at Rome.* But as the real length of the year is 365 days, 5 hours, 49 minutes, nearly, the manner of reckoning adopted by Julius Cæsar was not sufficiently exact to preserve the seasons in the same time of the year; for in four years the difference between the year thus regulated and the true solar year amounted to about 44 minutes, and in 132 years to one entire day. The Julian year must, therefore, have begun one day earlier than the solar year at the end of this period. Consequently, the continuance of this erroneous mode of reckoning would have made the seasons change their places altogether in the course of twenty-four thousand years.

At the time of the *Council of Nice*, in the year 325 of the Christian era, the Julian calendar was introduced into the church; and at that time the vernal equinox fell on the 21st of March; but on account of the imperfections of the mode of reckoning just noticed, the reckoning fell constantly behind the true time: so that in the year 1582, the Julian year had fallen nearly ten days behind the sun; and the equinox, instead of falling on the 21st of March, fell on the 11th of March.

The defects of the calendar were discovered long before the year 1582; but all attempts made to reform it proved in vain. At last, Pope Gregory, who was desirous of rendering his pontificate illustrious by bringing about a reformation, which his predecessors had failed to accomplish, invited all the astronomers in Christendom to give their opinions on this important affair. This invitation had the effect of bringing forth many ingenious plans, but the one which he ordered to be adopted was afforded by an astronomer of Verona, named Lilius.

The first step was to allow for the loss of the ten days; which was done by counting the 5th of October, 1582, the 15th of that month. By this means, the vernal equinox was again brought to the 21st of March, as it was at the time of the Council of Nice. And to prevent the like inconvenience in future, it was decreed that the last year of every century, not divisible by *four*, should be accounted a common year, which, according to the Julian reckoning, should be leap year; but that those hundreds which were divisible by four, such as 1600, 2000, 2400, &c. should still be accounted leap year. Although this correction be sufficiently exact to keep the seasons to the same time of the year, yet it does not altogether correspond with the *real length* of the year, for the time that the Julian year exceeds the true, will amount to 3 days in 390 years. If, therefore, at the end of 390 years, three days were expunged, the equinox would very nearly keep to the same day of the month; but by suppressing 3 days

* The intercalary day, or the day which was added every fourth year, was accounted the 24th of February, and called by the Romans the 6th of the Kalends of March; on this account there were every fourth year two 6ths of the Kalends of March, and therefore they called this year Bissextile. With us it is called Leap Year.

only in 400 years, as in the Gregorian account, a small deviation will take place in the course of twelve or sixteen centuries, but so trifling as scarcely to deserve notice.

As this reformation of the calendar was brought about under the auspices of Pope Gregory, it is called the Gregorian Calendar, and sometimes the *New Style*, to distinguish it from the Julian account. This new calendar was immediately adopted in all Catholic countries; but it was not adopted in this country till the year 1752. In Russia, Prussia, and some other countries, the Julian account is still used.

OF THE TIDES.

> The ebbs of tides, and their mysterious flow,
> He, as art's elements, shall understand.
>
> DRYDEN.

The Tides have been always found to follow, periodically, the course of the sun and moon; and hence it has been suspected, in all ages, that the tides were, some way or other, produced by these bodies.

The celebrated Kepler was the first person who formed any conjectures respecting their *true* cause. But what Kepler only hinted, has been completely developed and demonstrated by Sir Isaac Newton.

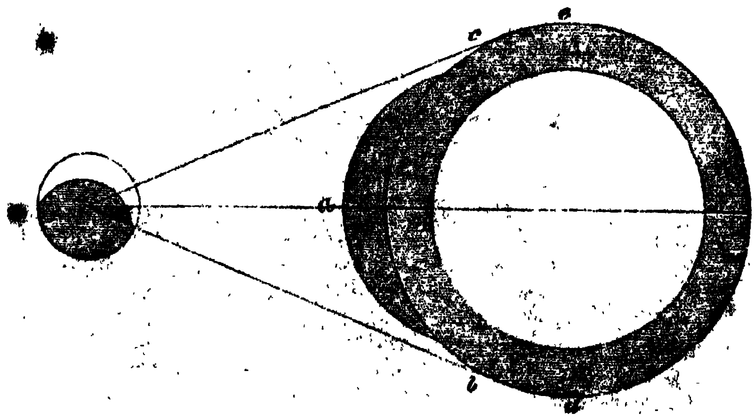
After his great discovery of the law of gravitation, he found it an easy matter to account for the whole phenomena of the tides: for, according to this law of nature, all the particles of matter which compose the universe, however remote from one another, have a continual tendency to approach each other, with a force directly proportional to the quantity of matter they contain, and inversely proportional to the square of their distance asunder. It is therefore evident, from this, that the earth will be attracted both by the sun and moon. But although the attraction of the sun greatly exceeds that of the moon, yet the sun being nearly four hundred times more distant from the earth than the moon, the *difference* of his attraction upon *different* parts of the earth is not nearly so great as that of the moon; and therefore the moon is the principal cause of the tides.

> Attractive pow'r! whose mighty sway
> The Ocean's swelling waves obey,
> And, mounting upward, seem to raise
> A liquid altar to thy praise.

If all parts of the earth were equally attracted by the moon, it would always retain its spherical form, and there would be no tides at all. But the action of the moon being unequal on different parts of the earth, those parts being most attracted that are nearest the moon, and those at the greatest distance least, the spherical figure must suffer some change from the moon's action. Now, as the waters of the ocean directly under the moon are nearer to her than the central parts of the earth, they will be more attracted by her

than the central parts. For the same reason, the central parts will be more attracted than the waters on the opposite side of the earth, and therefore the distance between the earth's centre and the waters on its surface, both under the moon and on the opposite side, will be increased; or the waters will rise higher, and it will then be flood, or high water, at those places. But this is not the only cause that produces the rise of the water at these two points; for those parts of the ocean which are 90° from them will be attracted with nearly the same force as the centres of the earth, the effect of which will be a small increase of their gravity towards the centre of the earth. Hence, the waters at those places will press towards the *zenith* and *nadir*, or the points where the gravity of the water is diminished, to restore the equilibrium, and thus occasion a greater rise at those points. But in order to know the real effect of the moon on the ocean, the motion of the earth on its *axis* must be taken into account. For if it were not for this motion, the longest diameter of the watery spheroid would point directly to the moon's centre; but by reason of the motion of the whole mass of the earth on its axis, from west to east, the most elevated parts of the water no longer answer precisely to the moon, but are carried considerably to the eastward in the direction of the rotation. The waters also continue to rise after they have passed directly under the moon, though the immediate action of the moon begins there to decrease; and they do not reach their greatest height till they have got about 45° farther. After they have passed the point which is 90° distant from the point below the moon, they continue to descend, although the force which the moon adds to their gravity begins there to decrease. For still the action of the moon adds to their gravity, and makes them descend till they have got about 45° farther; the greatest elevations, therefore, do not take place at the points which are in a line with the centres of the earth and moon, but about half a quadrant to the east of these points, in the direction of the motion of rotation.

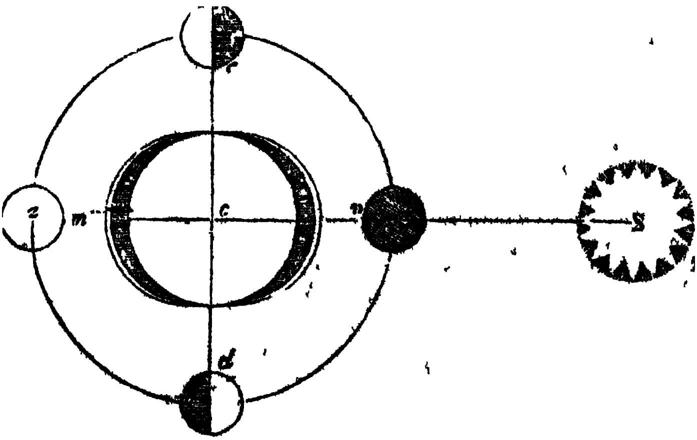
Thus it appears, if the earth were entirely covered by the ocean, as represented by the circle *b d e c* in the following figure,



that the spheroidical form which it would assume, would be so situated, that its longest diameter would point to the east of the moon, or the moon would always be to the west of the meridian of the parts of greatest elevation. And as the moon apparently shifts her position from east to west in going round the earth every day, the longer diameter of the spheroid following her motions will occasion two floods and two ebbs in the space of a lunar day, or 24 hours 48 min.

> The moon turns Ocean in his bed
> From side to side, in constant ebb and flow,
> And purifies from stench his wat'ry realms. YOUNG.

These are the effects produced by the action of the moon only; but the sun has also a considerable effect on the waters of the ocean, although it must be much less on account of his immense distance. For, as already observed, it is not the action of these bodies on the earth, but the inequalities of their actions which produce these effects. The sun's action on the whole mass of the earth is much greater than of the moon's; but his distance is so great, that the diameter of the earth is a mere point compared with it; and, therefore, the difference between his effects on the nearest and farthest side of the earth, becomes on this account vastly less than it would be if the sun were as near as the moon.* However, the immense bulk of the sun makes the effect still sensible, even at so vast a distance; and although the action of the moon has the greatest share in producing the tides, yet the action of the sun adds sensibly to this effect, when his action is exerted in the same direction, as at the time of *new* and *full moon*, when these two bodies are nearly in the same straight line with the centre of the earth. When this is the case, the effects of these two bodies are united, so that the tides rise higher than at any other time, and are called *spring tides;* as represented by the following figure, where S denotes the sun, *d n e z* the moon, and *c* the earth.



* The mean distance of the moon from the earth is 240,000 miles.

The action of the sun diminishes that of the moon in the quarters, because his action is opposed to that of the moon; consequently, the effect must be to depress the waters where the moon's action has a tendency to raise them. These tides are considerably lower than at any other time, and are called *neap tides*.

The *spring tides* do not take place on the very day of the new and full moon, nor the neap tides on the very day of the quadratures, but a day or two after; because in this case, as in some others, the effect is neither the greatest nor least when the immediate influence of the cause is greatest or least: as the greatest heat, for example, is not on the solstitial day, when the immediate action of the sun is greatest, but some time after it. And although the action of the sun and moon were to cease, yet the ocean would continue to ebb and flow for some time, as its waves continue in violent motion for some time after a storm.

The *high water* at a given place does not always answer to the same situation of the moon, but happens sometimes sooner and sometimes later than if the moon alone acted on the ocean. This proceeds from the action of the sun not conspiring with that of the moon. The different distances of the moon from the earth also occasions a sensible variation in the tides.

When the moon approaches the earth, her action in every part increases, and the differences in that action, upon which the tides depend, likewise increase. For the attraction of any body is in the inverse ratio of the square of its distance; the nearer, therefore, the moon is to the earth the greater is her attraction, and the more remote, the less. Hence, her action on the nearest parts increases more quickly than it does on the more remote parts, and therefore the tides increase in a higher proportion as the distance of the moon diminishes.

Sir Isaac Newton has shown that the tides increase as the cube of the distances decrease, so that the moon, at *half* her present distance, would produce a tide *eight times* greater. Now the moon describes an ellipse about the earth, and, of course, must be once in every revolution nearer the earth than in any other part of her orbit; consequently, she must produce a much higher tide when in this point of her orbit than in the opposite point.

This is the reason that two great *spring tides* never take place immediately after each other; for if the moon be at her least distance at the time of new moon, she must be at her greatest distance at the time of *full moon*, having performed half a revolution in the intervening time, and therefore the spring tide at the *full* will be much less than that at the preceding *change*. For the same reason, if a great spring tide happens at the time of *full moon*, the tide at the following *change* will be less.

The spring tides are highest and the neap tides lowest about the beginning of the year; for the earth being nearest the sun about the 1st of January, must be more strongly attracted by that body than at any other time of the year: hence, the spring tides which happen about that time will be greater than at any other time. And should

the moon be new or full in that part of her orbit which is nearest to the earth, at the same time the tides will be considerably higher than at any other time of the year.

The tide which happens at any time, while the moon is above the horizon, is called the *superior tide*, and the other the *inferior* tide. When the moon is in the equinoctial, other things remaining the same, the *superior* and inferior tides are of the *same* height; but when the moon declines towards the elevated pole, the *superior* tide is higher than the *inferior*. If the latitude of the place and the declination of the moon are of contrary names, the *inferior* tide will be the highest. But the highest tide at any particular place, is when the moon's declination is equal to the latitude of the place, and of the same name; and the height of the tide diminishes, as the difference between the latitude and declination increases; therefore, the nearer any place is to that parallel whose latitude is equal to the moon's declination and of the same name, the higher will be the tide at that place.*

Such would the tides regularly be if the earth were all covered over with the ocean to a great depth; but as this is not the case, it is only at places situated on the shores of large oceans where such tides, as above described, take place.

The tides are also subject to very great irregularities from local circumstances; such as meeting with islands, shoals, headlands, passing through straits, &c. In order that they may have their full motion, the ocean in which they are produced ought to extend 90° from east to west, because that is the distance between the greatest elevation and the greatest depression produced in the waters by the moon. Hence it is, that the tides in the Pacific Ocean exceed those of the Atlantic, and that they are less in that part of the Atlantic which is within the torrid zone, between Africa and America, than in the temperate zones, on either side of it where the ocean is much broader.

In the Baltic, the Mediterranean, and the Black seas, there are no sensible tides; for they communicate with the ocean by so narrow inlets, and are of so great extent, that they cannot speedily receive and let out water enough to raise or depress their surfaces in any sensible degree.

The power of the moon to raise the waters, Sir I. Newton has shown to be about $4\frac{1}{2}$ times that of the sun, and that the moon raises the waters 8 feet 7 inches, while the sun and moon together raise them $10\frac{1}{2}$ feet, when at their mean distances from the earth, and about 12 feet when the moon is at her least distance. These heights are found to agree very well with observations on the coasts of open and deep oceans, but not well on the coasts of small seas, and where the water is shallow.

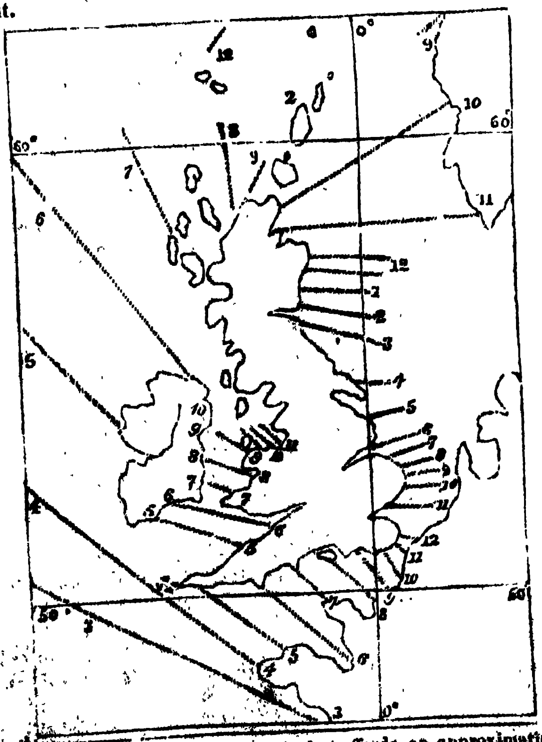
The mean retardation of the tides, or of the moon's coming to the meridian in 24 hours is $48' \, 45''{\cdot}7$, and the mean interval between two successive tides is $12^h \, 25' \, 14''{\cdot}2$; hence, the mean daily retardation of high water is $50' \, 28''{\cdot}4$.

* In comparing the height of the tides at different places, it is supposed that the sun and moon are at the same distances from the earth, and in the same position with respect to the meridian of these places.

About the time of *new* and *full* moon the interval is least, being only $12^h\ 19'\ 28''$; and at the quadratures the interval is the greatest, being $12^h\ 30'\ 7''$

The common method of calculating the time of high water at any place is to multiply $50'\ 28''$, or the mean daily retardation of the tides, by the moon's age, and then to divide the product by 60, which gives the mean time of the moon coming to the meridian on that day, in hours; to this is added the time of high water on the days of *full* and *change* at the given place, and the sum is the time of high water at that place on the *afternoon* of the given day, if the sum be less than 12 hours; but if greater, 12 hours 25 minutes must be subtracted, in order to have the time on the afternoon of the given day; and 25 minutes subtracted from this time will give the time of high water on the morning of the given day.*

The following figure exhibits the progress of the tides from the Atlantic through the channels surrounding the British islands; the lunar tides happening in any part of the shaded lines nearly at the hour after the moon's southing, which is indicated by the figure annexed to it.



* This method is far from being exact; but affords an approximation, which may be useful on some occasions. When accuracy is wanted, recourse must be had to other methods; some of which will be given in the Supplement to this work.

OF THE FORCES WHICH RETAIN THE PLANETS IN THEIR ORBITS.

Thine these noble works
Great universal Ruler!
Thy virtual energy the frame of things
Pervading actuates; as at first thy hand
Diffused through endless space this limpid sky,
Vast ocean without storm, where these huge globes
Sail undisturbed, a rounding voyage each;
Observant all of one unchanging law.
Simplicity divine! by this sole rule,
The Maker's great establishment, these worlds
Revolve harmonious, world attracting world
With mutual love, and to their central sun
All gravitating. MALLET.

Before the time of Kepler, who flourished about the end of the 16th century, the planets were supposed to move in *circular* orbits; but since his great discovery of the laws which regulate the motions of these bodies, astronomers have been enabled to determine their periods, and the figures of their orbits, with the greatest exactness.

The laws of Kepler are,

1. That all the planets move round the sun, in such a manner, that the *radius vector*, or a line joining the sun and planet, passes over equal areas or spaces of the orbit in equal portions of time.

2. That each of the primary planets describes an ellipse, having the sun in one of its foci.*

3. That the squares of the periodic times of the planets are to each other as the cubes of their mean distances from the sun.

These three laws are the basis of all physical astronomy. But in a popular work like the present, it would be improper to enter upon any demonstrations of them. However, as it may, perhaps, gratify the reader to see an illustration of the *third* law, we shall give an example, by comparing the distance and periodic time of Mercury with those of the earth.

Suppose the distance of Mercury were given, and it was required to find the time it required to perform a revolution round the sun, having the distance of the earth from the sun and the length of the year given. By the third law of Kepler it would be determined thus:—As the cube of the earth's distance (95^3 millions of miles) is to the cube of Mercury's distance ($36\frac{1}{2}^3$ millions), so is the square of the earth's periodic time ($365\frac{1}{4}^2$ days) to the square of Mercury's year (88^2 days nearly).

The *distance* may also be found by the same law, if the periodic time be known. Let it be required to find the distance of Mercury, having its periodic time given, then it would be determined thus: as the square of $365\frac{1}{4}$ days is to the square of 88 days, so is the cube of 95 millions of miles to the cube of $36\frac{1}{2}$ millions of miles, the dis-

* See fig. page 10.

tance of Mercury from the sun. In the same way, the *distance* of any other planet may be determined, if its period be known; or its period, if its distance be known.*

After the laws of gravitation were known, it was demonstrated by Sir Isaac Newton, *à priori*, that the laws of Kepler must be those that regulate the system of the world.

This extraordinary man found that the laws of motion, and even the general properties of matter, are the same in the heavens as on the earth. That the elliptical figure of the orbits described both by the primary and secondary planets; the small deviations in the form and position of their orbits, as well as in the place of the planets; the facts which concern the shape, rotation, and position of their axis; and the oscillation of the waters which surround the earth, are all explained by *one principle;* namely, that of the mutual gravitation of all bodies with forces *directly* as their quantities of matter, and inversely as the squares of their distances.

But as we cannot follow this *celebrated* philosopher in all his demonstrations on this important subject, in a work of this kind, we shall endeavour to give as clear and comprehensive a view of the doctrine of gravitation, as our limits will permit, at the same time avoiding every thing abstruse.

Thus, if one body contains double the quantity of matter that another contains, its attractive power will also be double; if it contains *ten* times the quantity of matter, its attractive power will be ten times greater, and so on.

But if a body be placed at any distance from another body, and then removed to double the distance, it will attract it only with a fourth part of the force it did before; at three times the distance, with a ninth part of the force; and at four times the distance only with a sixteenth part, and so on.

These are termed the laws of gravitation; and are known to affect every species of matter, and to connect the most distant bodies in the universe. But what the power or principle is which causes bodies to affect each other according to these laws, we shall not attempt to enquire: because any enquiry of this kind is not likely to be attended with much success. Nor is it necessary to know the cause which produces these effects; for all that the astronomer is concerned to know is, whether such a power or force is exerted by one body on another; and if it is, what are the laws of its action. Now both of these important facts have been determined with the greatest precision, not only by calculation, but by observation and experiment.

Every person knows that a heavy body dropped from any height above the earth's surface descends in a straight line towards the centre of the earth, where the whole force of gravity seems to be accumulated. And although it be difficult to discover any sensible change in the intensity of this force by a direct experiment on the weight of a body, on account of the distances to which we can either

* In order to perform the calculation in this example, it is necessary to be acquainted with proportion, and the method of extracting the square and cube roots.

ascend or descend from the earth's surface being so small; yet the experiments which have been made with the pendulum, lead us to infer, that the force of gravity diminishes as we recede from the centre of the earth, at the rate we have stated above, namely, as the square of the distance increases. The effect of terrestrial gravity, as exhibited in the descent of falling bodies, has been accurately measured, and the law which it observes fully ascertained and confirmed. It had been long known that falling bodies acquire an increase of velocity as they approach the earth; and consequently that they pass over a greater space in any given time. But Galileo was the first person who made known the law which regulates their descent, which is as follows: When a body falls freely from a state of rest, it passes through the space of sixteen feet one inch in the first second of time; and at the end of the first second it will have acquired such a degree of velocity as would carry it thirty-two feet two inches in the next second, though it should acquire no new impulse from gravity. But as the same accelerating cause continues constantly to act, it will move sixteen feet and one inch more the next second; consequently at the end of two seconds it will have fallen sixty-four feet four inches, and acquired such a velocity as would, in the next second, carry it over forty-eight feet, although it received no new impulse, and so on. If a body be projected perpendicularly upwards, its motion is continually retarded by the same cause which accelerates it in descending. But if it be projected in a direction different from the vertical line, that direction will be continually varying, and a curved line will be described in consequence of the incessant power of gravity, which, in such cases, is measured by the degree of curvature of the line described by the body.

This phenomenon affords a very good illustration of the theory of the planetary motions; for the effect produced is perfectly analogous to the motion of a planet in its orbit. Every person knows that the greater the velocity with which any body is thrown, in a horizontal direction, from an engine, the further will it range before it falls. And though a body cannot be thrown to a very great distance on the earth, yet we can conceive a body projected with such a velocity as to carry it quite *round* the earth without touching it, and to continue to circulate round it in the same path with undiminished velocity, in every respect as the moon does. By reasoning in this manner, Sir Isaac Newton conceived, that the force that produces pressure in a body that is supported, or that causes a heavy body to fall to the ground, or a body thrown obliquely in the air, to describe a curvilineal path, might perhaps be the same that retains the moon in her orbit; and makes the planets and comets revolve round the sun. Though this was at first only a plausible conjecture, yet, upon an appeal to the phenomena exhibited by these bodies, he was enabled to verify this conjecture.

It was, however, a fortunate circumstance for science, as well as for Newton, that the real motions of the heavenly bodies, as well as the laws of Kepler, were known before he undertook the investigation of this subject. For these laws were not only the basis upon which

he founded his investigations, but they suggested to him the manner of conducting them.

The first law, for example, led him to the important discovery, that the action of a force always directed towards the sun *bends* the path of each planet into a curve; and the second law not only led him to the knowledge of the changes produced in the intensity of this force, by distance, but to the law which regulates the intensity.

And as it was previously known that the planets move round the sun in elliptical orbits, he was enabled to establish this important law, that the force by which a planet describes areas proportional to the times round the focus of its elliptical orbit, is inversely as the square of the distance from that focus. Hence it follows, that each planet is under the influence of a force directed towards the sun, and urging it in that direction, and that the intensity of this force is inversely proportional to the square of the planet's distance from the sun.

This power or force is sometimes called the *centripetal* force; because it urges the planet in the direction of the centre of its orbit, and prevents it from flying off in a straight line, which every body moving in a curve has a tendency to do; and that force by which it is urged in a straight line, or endeavours to fly off from the centre, is called the *centrifugal* force. It is by the nice combination of these two forces, that the whole solar system is preserved in the order in which we behold it, and that every body which forms any part of the whole, performs its revolution round the common centre of the system.

If the projectile or centrifugal force that urges the planets forward in their orbits were destroyed, each of them would fall to the sun, by the force of gravity, just as a stone descends to the earth.

The time in which the different planets would fall to the sun, from a state of rest, by the action of the centripetal force, or the power of gravity, is as follows:—Mercury, in 15 days 13 hours; Venus, 39 days 17 hours, the Earth, 64 days 13 hours; Mars, 121 days 10 hours, Jupiter, 765 days 10 hours; Saturn, 1901 days; Uranus, 5425 days; and the Moon to the Earth, in 4 days 20 hours.

As the centripetal force or attractive power of the sun *increases* as the square of the distance *decreases*, it is obvious that the nearer any body is to the sun, the more powerfully will it be attracted by him. This not only accounts for the planets which are nearest the sun moving faster in their orbits than those that are most remote from him; but also for the motion of a planet being quickest in that part of its orbit which is nearest the sun, and slowest in that part which is farthest distant from him.* For the centrifugal force must always be equal to the centripetal, in order that the planet may continue to revolve in the same orbit. In this manner, all the bodies which compose the solar system are attracted by the sun, and made to perform their revolutions round him; and as *action* and *re-action* are equal, and in opposite directions, the sun is equally attracted by all the bodies that revolve round him. Hence the order and regularity of the whole system is preserved.

* See page 10.

As neither our limits nor the nature of the present work will permit us to give a particular account of the planetary disturbances, or the effect which they have on each other, we shall conclude the present article by mentioning the discoveries which have been the result of the investigations of astronomers on this intricate subject. These may be reduced to the two following; viz. 1st. That all the inequalities produced by the mutual action of the planets are periodical; that is, after a certain time they all run through the whole series of changes to which they are subject: 2d. That amid all these changes, two of their elements remain the same—the greater axis of the orbit, and the periodic time. Hence, the mean motion of a planet, and its mean distance, are constant quantities. For these important discoveries we are indebted to the celebrated French mathematicians, La Grange and La Place. And, as the late Professor Playfair has observed, they have made known to us one of the most important truths in Physical Astronomy; namely, that the system is stable; that it does not involve any principle of destruction in itself; but is calculated to endure for ever, unless the action of an external power be introduced.

OF THE QUANTITY OF MATTER IN THE SUN AND PLANETS,

AND THE FORCE OF GRAVITY AT THEIR SURFACES.

On first view, it almost appears impossible to determine the respective masses of the sun and planets, and to measure the height from which bodies fall in a given time, by the action of gravity at their surfaces. But the connection of facts with each other, often leads to results which appear inaccessible, when the principle on which they depend is unknown.

It was, therefore, perfectly natural even for astronomers to consider it impossible to determine the intensity of gravity at the surface of the planets, while the principle of universal gravitation remained unknown;* and it is just as natural for those who are unacquainted with mathematics and astronomy to consider the same thing impossible, even although they have heard of such a principle as universal gravitation. We shall, therefore, state what has been the result of the calculations of some of the first-rate astronomers of the present day on this curious and interesting subject.

From the fact that action is always accompanied by re-action, astronomers conclude, that gravitation among terrestrial bodies is the mutual tendency of the particles of matter to one another. And, from analogy, they think it perfectly reasonable to suppose, that this is true in all cases; and that the force of gravitation towards different

* It was this discovery which rendered it practicable to measure the intensity of gravity at the surfaces of the planets.

bodies, the distance being the same, is proportional to the quantities of matter, or the masses of the bodies.

This supposition is the foundation of all the calculations respecting the masses of the planets; and from it formulas have been deduced for calculating the relative quantity of matter in such of the primary planets as have satellites revolving round them; but the quantity of matter in those that have no satellites can only be guessed at by the effect they produce in disturbing the motions of the other planets.*

The quantity of matter in the moon, however, may be determined by comparing its influence with that of the sun in producing the tides, and the precession of the equinoxes. By these means it has been ascertained, that the mass of the moon is about $\frac{1}{70}$th part of that of the earth. And La Place, in his *Mecanique Celeste*, has determined the quantity of matter in each of the primary planets, from the most exact data, to be as follows:—

Quantity of matter in the Sun	. . . .	1
Mercury	. . . .	$\frac{1}{2025810}$
Venus	. . . .	$\frac{1}{383137}$
The Earth	. . . . .	$\frac{1}{329630}$
Mars	. . . .	$\frac{1}{1846082}$
Jupiter	. . . .	$\frac{1}{1067 \cdot 09}$
Saturn	. . . .	$\frac{1}{3359 \cdot 4}$
Uranus†	. . . .	$\frac{1}{19504}$

The masses of the planets being known, and their bulks being also known, their densities are easily determined, for these are proportional to the masses divided by the bulks.

La Place, taking the mean density of the sun as *unity*, finds the density of such planets as have satellites to be as follows:— The Earth, 3·9395; Jupiter, 0·8601; Saturn, 0·4951; Uranus, 1·1376.

Knowing the masses of the planets, and their diameters, the force of gravity at their surface may be determined; for, supposing them to be spherical, and to have no rotation on their axis, the force with which a body placed on their surface gravitates to them, will be proportional to their masses divided by the squares of their diameters. From the masses of Jupiter and the Earth, La Place calculates that a body which weighs one pound at the earth's equator, if carried to Jupiter's equator would weigh 2¼ pounds, supposing these bodies to have no rotation, and supposing the weights to be measured by the pressure exerted in the two situations. If the same body were carried to the surface of the sun, it would weigh about 27$\frac{2}{3}$ pounds; from which it follows, that a heavy body would there descend about 444 feet in the first second of time.

* The quantities of matter in any two primary planets are directly as the cubes of the mean distances at which their satellites revolve, and inversely as the squares of their periodic times.

† By adding these fractions together it will be found that the quantity of matter in all the planets together is not $\frac{1}{700}$th part of the matter in the sun!

Although all the planets gravitate to the sun, yet the centre of the sun is not the centre of gravity of the whole solar system. The centre of the sun is, however, never distant from that point so much as his own diameter, consequently the centre of gravity of the whole system is always within the body of the sun. But as this point and the centre of the sun do not coincide exactly, and as the gravitation of the planets to the sun must be accompanied by the gravitation of the sun to the planets, from the quality of action and re-action, it follows that the sun must have a motion in a small orbit round the centre of gravity of the whole system. The form of this orbit is, however, very complicated, on account of the disturbing forces of so many planets, which are sometimes exerted toward one side and sometimes toward another; and even unequally exerted on different sides at the same time, according to the situation of the planets in their orbits.

Thus we see the extraordinary and universal principle called gravitation has not only been the means of making us acquainted with a great number of inequalities in the motion of the heavenly bodies, which it would have been impossible to have discovered by observation, but it has furnished us with the means of subjecting these motions to precise and certain rules.

The motion of the earth, which had obtained the assent of astronomers, on account of the simplicity with which it explained the celestial phenomena, has received a new confirmation, which has carried it to the highest degree of evidence of which physical science is susceptible. Without the knowledge of this universal principle, the ellipticity of the planetary orbits; the laws which the planets and comets obey in their revolution round the sun; their secular and periodical inequalities; the numberless inequalities of the moon, and the satellites of Jupiter; the precession of the equinoxes; the nutation of the earth's axis; the motions of the lunar axis; and the ebbing and flowing of the sea, would only be insulated facts, and unconnected phenomena. It is, therefore, a circumstance which can scarcely be sufficiently admired, that all these phenomena, which at first sight appear so unconnected, should be explained by *one principle*—that of the mutual gravitation of all bodies with forces directly as their quantities of matter, and inversely as the squares of their distances.

OF THE PRINCIPAL SYSTEMS OF ASTRONOMY,

WHICH HAVE BEEN PROPOSED TO ACCOUNT FOR THE CELESTIAL PHENOMENA.

After the description which has been given of the various phenomena of the heavens, both as viewed with the naked eye and the telescope, it may not be unnecessary, nor unacceptable to the reader, to give a short account of the principal theories, or systems, which have been formed at various periods to account for some of these appearances, and particularly for the apparent motions of the celestial [bod]ies.

The explanation of the celestial motions which naturally occurred to those who began the study of the heavens, was, that the stars are so many luminous points fixed in the surface of a sphere, having the earth in its centre, and revolving on an axis passing through that centre, in the space of twenty-four hours. When it was observed, that all the stars did not partake of this diurnal motion in the same degree, but that some were carried slowly towards the east, and that their paths estimated in that direction, after certain intervals of time, returned into themselves, it was believed that they were fixed in the surfaces of spheres, which revolved westward more slowly than the sphere of the fixed stars. The spheres were supposed transparent, or made of some crystalline substance, and from this arose the name of the crystalline spheres, by which they were distinguished. Though this system grew more complicated, as the number and variety of the apparent phenomena increased, yet it was the system of Aristotle and Eudoxus; and, with few exceptions, of all the philosophers of antiquity.*

But when the business of observation came to be regularly pursued, little was said either of the fixed stars, or of the crystalline spheres; astronomers being chiefly bent on ascertaining the laws or general facts connected with the motions of the planets.

To do this, however, without the introduction of hypothesis, at this period, was scarcely possible. The simplest and most natural hypothesis was, that the planets moved eastward in circles, at a uniform rate. But when it was found that, instead of moving uniformly to the eastward, every one of them was subject to great irregularity, the motion eastward becoming slower, at certain periods, and at length vanishing altogether, so that the planet became stationary, and afterwards acquiring a motion in the contrary direction, and proceeded for a time to the westward, it was far from obvious that all these appearances could be reconciled with the idea of a uniform circular motion.

The solution of this difficulty is attributed to Apollonius Pergæus, one of the most celebrated mathematicians of antiquity. He conceived that each planet moved in a small circle, and that the centre of this small circle moved in the circumference of a large circle, which had the earth for its centre. The first of these circles was called the *epicycle*, and the second the *deferent*; and the motion in the circumference of each was supposed uniform. Lastly, it was conceived that the motion of the centre of the epicycle in the circumference of the deferent, and likewise the motion of the planet in that of the epicycle, were in opposite directions; the first being towards the east, and the scond towards the west. In this way, the change

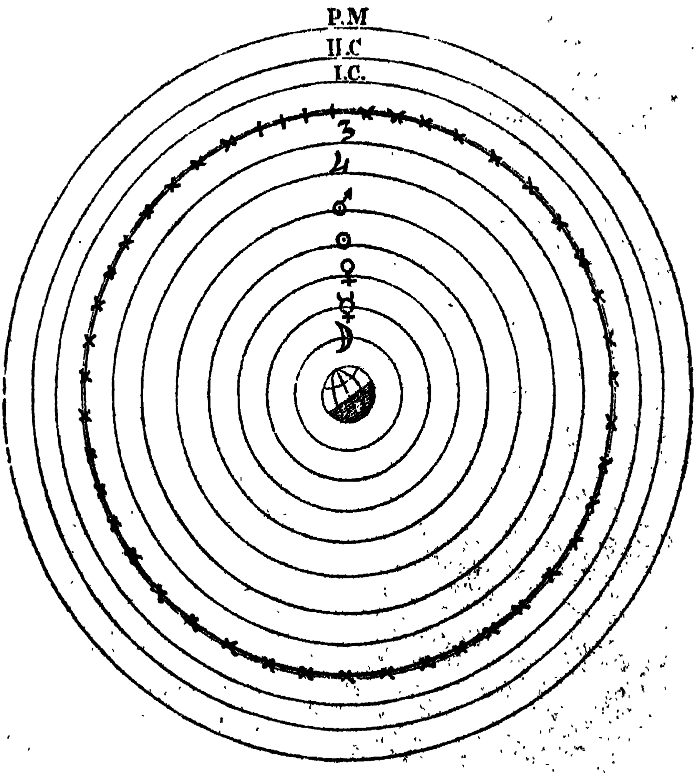
* Although it is said that Pythagoras taught that the earth was a planet, and that the sun was fixed in the centre of the planetary system; that the apparent revolution of the heavens was produced by the diurnal revolution of the earth; and that the apparent annual motion of the sun was occasioned by the earth moving round him like the other planets; yet this doctrine was never taught publicly, and in a very short time it was completely forgotten

from progressive to retrograde, as well as the intermediate stationary points, were readily explained.

But, notwithstanding the accomplishment of this important object, and some further applications of the method of epicycles by Hipparchus, to account for the inequality of the sun's apparent motion round the earth, no regular system of astronomy appears to have been framed or taught by any individual till the appearance of the celebrated Ptolemy, who has always been reckoned the prince of ancient astronomers, not so much on account of being the founder of the system which goes by his name, as for the number of observations which he made, and the extent of his astronomical writings.

PTOLEMAIC SYSTEM.

Ptolemy supposed the earth to be fixed immoveably in the centre of the universe, and that the sun, moon, and planets move round it in the following order; viz. The Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn, as represented by the following figure.



Above these he placed the firmament of fixed stars, then two crystalline spheres; all of which were included in what he called the *primum mobile*, which was by some unaccountable means turned round once in twenty-four hours, carrying all the rest along with it.

From this arrangement, in which the sun is placed between Venus and Mars, it appears, that he was acquainted with the common distinction of inferior and superior planets. It appears, also, that the arrangement of the planets in the above order, was made on considering the time which each of them required to perform a complete circuit of the heavens; hence we find the moon placed nearest to the earth. Although he could explain the respective motions of the planets round the heavens, from west to east, as well as their diurnal motion round the earth, yet he was obliged to have recourse to the epicycles of Apollonius to explain the apparent irregularities in their motions, such as appearing to be stationary, retrograde, &c.

In order to account for the inclination of the respective orbits of the planets to the ecliptic, it was said, that the *deferent* and epicycle were in different planes from the ecliptic. And when any new and anomalous motion was detected, another epicycle was immediately added to explain the appearance.

In this way, by means of the most extravagant suppositions, and complicated machinery, a system was at length formed, which explained, in a plausible but conjectural manner, most of the constant phenomena of the heavens. But the awkward and complicated machinery by which it is supported, when compared with the simplicity of the Copernican system, is almost sufficient to cause it to be rejected. Besides the whole theory is entirely hypothetical; and that the existence of the agents employed to produce such mighty effects has never been attempted to be proved. But, independent of these objections, this system is now found to be at complete variance with many of the modern discoveries which have been made, respecting comets; for the orbits of these bodies are known to cross those of the planets in every direction; a fact which is quite incompatible with the existence of crystalline spheres. And the constant periodical motions and appearances of the two inferior planets, Mercury and Venus, completely refute the whole system. For if this system were true, these two planets could never be hid behind the sun, because their orbits are included in his, according to Ptolemy's hypothesis. These motions, too, would always be direct, and they would appear as often in opposition to, as in conjunction with, the sun: but the contrary of all this takes place; for these two planets are just as often behind the sun as before him—appear as often to move backward as forward—and, instead of being seen at any time in that side of the heavens which is opposite to the sun, they were never yet seen a quarter of a circle distant from him; which certainly proves that the Ptolemaic system is contrary to what actually takes place in nature: and yet it continued to receive the sanction both of the learned and unlearned, for nearly fourteen hundred years, without the truth of it ever being publicly called in question.

COPERNICAN SYSTEM.

The celebrated astronomer Copernicus, was the person who gave the death-blow to the system of Ptolemy, by conceiving the bold system which removes the earth from the centre of the world, and ascribes to it a two-fold motion.*

Copernicus was first led to turn his attention to the framing of a new theory, from a perception of the complexity, or rather absurdity of the doctrine of epicycles. In the early part of his life he began to consider whether a more rational and satisfactory manner of accounting for the apparent motions of the heavenly bodies could not be discovered, than that which was given by Ptolemy. By intense application to the subject, and a few obscure hints obtained from the ancients, he at last deduced a complete system, capable of solving every phenomena in a more simple and satisfactory manner than was ever done before.

In this system the sun is placed in the centre, and the planets move round him in the following order; viz. Mercury, Venus, the Earth, Mars, Jupiter, Saturn; and far beyond the orbit of Saturn are placed the fixed stars, which form the boundary of the visible creation.† This is the system which is now generally received by all modern astronomers, and the one upon which all the phenomena, mentioned in the preceding pages, have been accounted for and explained.

It may, perhaps, be proper to notice some objections which have repeatedly been advanced against it, especially as these were not noticed when treating of the annual and diurnal motions of the earth. This we shall however defer till we have given a short account of the Tychonic System; because its author was one of the most ingenious and powerful opponents that ever appeared against the Copernican System.

TYCHONIC SYSTEM.

Although the Copernican System was received by most men of science then living, yet there were some who would never assent to it. The motion of the earth was so contrary to what they were always accustomed to hear on the subject, and, as they thought, to appearances, that they could never agree to support such doctrine.

Among those who opposed the system of Copernicus, was Tycho Brahe, a Danish nobleman, who was born in the year 1546, and who devoted the whole of his life to the study of astronomy. As he could not entirely adopt the Ptolemaic system, being convinced that the earth is not the centre about which the *planets* revolve, and being a man of genius, he invented a *new* system, which was a kind of mean between the Ptolemaic and the Copernican.

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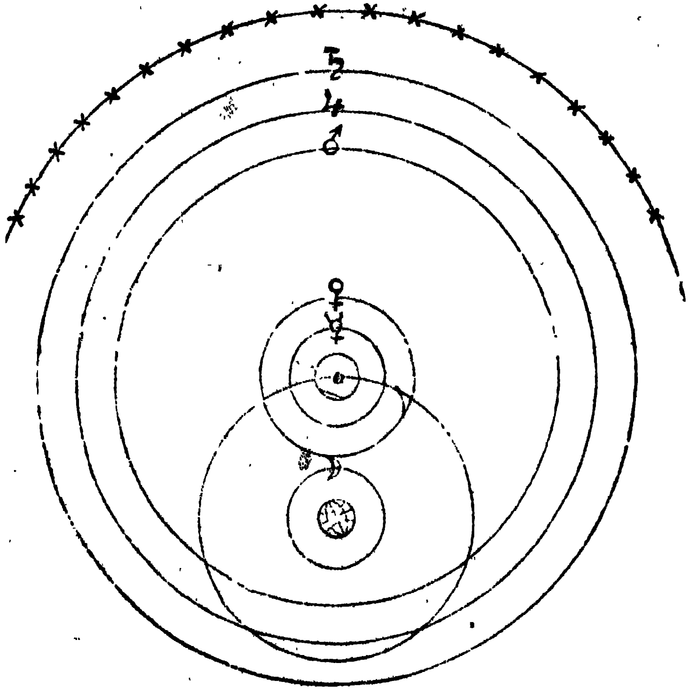
* The diurnal and annual.—See pages 120 and 122.

† See page 13.

In this system, the earth is placed in the centre of the orbits of the sun and moon; but the sun is supposed to be the centre of the orbits of the five primary planets then known. Thus, according to Tycho Brahe, the sun and all the planets moved round the earth, in order to save the earth from revolving on its axis once in twenty-four hours!

This System is represented by the following figure.



It must be allowed, that all the phenomena purely astronomical may be accounted for on this hypothesis; and that the objections to it are rather derived from physical and mechanical considerations, than from the appearances themselves. It is simpler than the Ptolemaic system, and free from its inconsistencies; but it is more complex than the Copernican, and in no respect affords a better explanation of the phenomena. Its true place is between these two systems; an advance beyond the one, and a step short of the other. If its author had lived before Copernicus, it would have been a step in the advancement of knowledge; but coming after him, it was a step backward.

It is certainly not to his credit as a philosopher to have made this retrograde movement, yet he is not altogether without apology. For the physical arguments in favour of the Copernican system could not

be supposed to have much weight in an age when the laws of motion were unknown, and when it was not clearly understood that the sun and planets had any effect on each other. Having already fully and clearly established both the diurnal and annual motion of the earth, and having advanced some other convincing arguments in favour of the Copernican system, in the former part of this work, it would be superfluous to enter into a formal refutation of the Tychonic system, which is so different from that of the Copernican.

But as Tycho Brahe advanced a number of objections against the Copernican system, and particularly that part of it which supposes the earth in motion, we shall here notice a few of those objections which appear to have the greatest weight, although the arguments already advanced in support of the annual as well as the diurnal motion of the earth, would be considered as equivalent to a demonstration by any person who was not previously prepossessed against the possibility of such motions.

Tycho asked, how was it possible for a ball which was projected perpendicularly up in the air, to fall down on the same spot from which it was projected if the earth revolved on its axis? In answer to this objection, it will be sufficient to observe, that the atmosphere which surrounds the earth revolves with it, having received the same common motion, in the same direction; and that every thing on the earth revolves with it, and retains the same relative position. It is rather astonishing that Tycho, and all those who have repeated the same argument, in various forms, never observed that when balls or billiards are played in a vessel sailing with the greatest velocity, that the shock of the ball is there given with the same force the one way as the other; and that when a stone is dropped from the top of the mast, it falls just as near the foot of it when the vessel sails as when she is at rest. But though this be the case, the stone has actually been carried some distance, in the direction of the ship's motion, from the point perpendicularly under that from which it was dropt: and if a spectator in another vessel at rest were to observe the stone during its descent, he would see it describe an oblique line, or the diagonal of a parallelogram, the sides of which would be the height of the mast, and the distance which the ship sailed during the time of the stone's descent. The motion of the vessel is communicated to the mast, to the stone, and to every thing on board, in such a way, that every thing thrown or moved arrives at the same point, and strikes with the same force, when the ship sails as when she is at rest, provided it be thrown with the same velocity in the one case as in the other.

The reason that the stone is seen to describe an oblique line, or even to have any motion at all, is its meeting or passing other objects in its descent which are known to be fixed. But as the earth meets with no other object, there is nothing at a distance from it, nor on its surface, which can by its situation, by its motion, or by its resistance, make us perceive or feel either its annual or diurnal motion. All bodies on or near the surface of the earth partake of the motion of the earth itself, and are carried smoothly through the air with the same

velocity, and continue to preserve the same relative position with respect to each other.

"The earth," said Tycho Brahe, to the followers of Copernicus, "is a heavy inert mass, very ill adapted to motion, and seems only fitted to be the fixed foundation of all stability; and yet you wish to make it a *star*, and travel about in the air! That is too strange an idea!"

But there is nothing in this remark of Tycho's which carries with it the smallest degree of evidence against the motion of the earth. Why not the earth move which is so much less than the sun, even following the observations and demonstrations of Tycho himself? Why should it be viler or grosser than the planets, which are round like the earth, opaque and dark like it, when the sun does not shine on them, and some of them much larger, even according to Tycho?

Another thing which shocked Tycho very much was the enormous distance at which the fixed stars must be placed in the system of Copernicus; for the breadth of the earth's orbit is an insensible point compared with their distance. "It is not probable," said he, "that the distance between Saturn and the fixed stars is seven hundred times greater than the distance between Saturn and the sun, without other stars being placed in the interval!" But this distance cannot be less, since it is found that the annual parallax of none of the fixed stars amounts to two seconds of a degree. And as this is the angle under which the earth's orbit appears when viewed from a fixed star, if it be equal to the angle under which we see the star, it follows that the star and orbit are equal in magnitude.

Now, as the parallax of the stars is so small as scarcely to amount to one second, they must either greatly exceed the earth's orbit in diameter, or be immensely distant from the earth.* But if Tycho had lived at the present day, he would not have advanced this objection against the motion of the earth; for he would have learned that the planet Uranus, as well as many of the comets, moved in orbits which extend far beyond that of Saturn, and fill a part of that immense space which appeared to him so inconceivable. He would have known by the discovery of telescopes, that the apparent diameter of stars of the first magnitude, does not amount to *one* second; and of course we are not under the necessity of supposing them so prodigiously great as if it amounted to two or three minutes, as he supposed. And though it should be admitted that there exists an immense interval void of stars and planets, and that the fixed stars are incomparably greater than the sun, it proves nothing against the system of Copernicus.

That the stars become nearer and smaller in the system of Tycho, are things too vague to prove any thing in his favour; because we have no more knowledge respecting their real *size* than their *true distance*.

Tycho also asked, how it was possible for the earth to preserve the

* According to Tycho, the apparent diameter of the stars of the first magnitude was two or three minutes!

parallelism of its axis during the whole of its revolution round the sun, or how one and the same body could have two different motions, one of which transports the centre of the globe, and the other which changes the position of its axis? But although the axis continues to maintain its parallelism during the whole of its annual revolution, this is not a peculiar motion as Tycho supposed, and forming a third motion, in the sense which Copernicus views motion. It is a situation natural to the axis, which does not change, for there is no cause to make it change.

It is sufficient that the axis has once been directed to a particular point in the heavens, for it still continues to be directed there, though the earth itself be constantly moving forward in its orbit. There is no physical nor mathematical reason from whence it can be concluded, that the axis would be perpendicular to the plane of the orbit, if the earth had a motion on its axis--there is no connection between these two motions.

In the time that all parts of the earth are thrown from the same side by a projectile force, they all acquire the same velocity, as well as a parallel direction; but this change does not affect the parts with respect to each other, nor in the least alter the position which they ought to have. All parts receive the same impression; there is a perfect equilibrium between the superior and inferior parts; and they all preserve the motion of rotation which they had before, or each particle moves in a direction parallel to that which it had when the earth was at rest.

A body having begun to move round its axis, the two poles, or the two immoveable points round which the body turns, receive the same motion by impulse from the centre which produces the motion of translation: and if they receive the *same* motion, there is no reason for supposing that one of these points advances faster than the other; and as the two make equal advances, they will necessarily be always in a line parallel to that in which they were when they began to move.

When a top turns upon a table by a rotatory motion, the table may be moved either up or down, or from right to left, obliquely or circularly, without occasioning any difference in the movement of the top. The top may also be thrown in any direction whatever, and yet continue to turn on the same axis. A ball thrown from the mouth of a cannon almost always turns round an axis, and although that axis may sometimes be vertical, horizontal, or inclined, yet this depends on the obstacles which it meets with in one or other of these directions before it leaves the mouth of the cannon. But as the earth meets with no obstacle in its revolution, the axis always continues to point in the same direction.

As the annual and diurnal motions of the earth are the foundation of all astronomy, both physical and practical, we have been at parti*cular pains to refute the objections* which have been started against these motions by the celebrated Tycho Brahe, because they are the strongest philosophical arguments that have ever been urged against the Copernican system. But had Tycho known what has been dis-

covered since his death he would not have started many of th objections which he has done against this system.

CARTESIAN SYSTEM.

The next system was the *Cartesian*. Its founder, Rhènè Des Cartes, flourished about the beginning of the 17th century. He supposed that every thing in the universe was formed from very minute bodies, called *atoms*, which had been floating in open space. To each *atom* he attributed a motion on its axis; and he also maintained that there was a general motion of the whole universe round like a *vortex*, or whirlpool. In the centre of this *vortex* was the sun, with all the planets circulating round him at different distances; those that were nearer the sun circulating faster than those at a greater distance, as the most distant parts of a vortex or whirlpool are known to do. Besides this general vortex, each of the planets had a particular vortex of its own, by which its satellites, if it had any, were whirled round, and any other body that came within its reach.

This is the celebrated system of vortices, invented by Des Cartes. The fabric, it must be confessed, is raised with great art and ingenuity, and is evidently the produce of a lively fancy and a fertile imagination. But then, it can be considered only as a philosophical romance, which amuses without instructing us; and serves principally to shew that the most shining abilities are frequently misemployed.

In this hypothesis, Des Cartes supposes extension to constitute the essence of matter, and wholly neglects *solidity*, as well as the *inertia* by which it resists any change in its state of motion or rest, which principally distinguishes body from space; and, consequently, the doctrine of an universal plenum, deduced from this definition, is founded upon false principles.

That there is such a thing as a vacuum in nature, or a space void of body, may be demonstrated from various experiments. By means of the air-pump, we can so far exhaust the air from a glass receiver, that a piece of gold and a feather, let fall together, from the top of the vessel, shall both descend equally swift, and come to the bottom at the same time: which evidently shews, that, the air being taken away, there remains no other matter sufficient to cause any sensible resistance, or that in the least impedes or obstructs their passage.

It was said by many of the ancient philosophers, that nature abhors a vacuum; and by means of this dogma, and others of a like nature, they attempted to prove and illustrate the doctrine of an universal plenum, like that of Des Cartes. But this is an assertion, unsupported by facts, and too idle a notion to require any formal refutation: and in nearly the same predicament are most of the other arguments which have been used in defence of this doctrine. They are all sufficiently exposed, not only by the Torricilian experiment, and the nature of pumps in general, but likewise from the most obvious phenomena of the constant and free motion of bodies, whether celestial or terrestrial, which come continually under our inspection.

On the system of Des Cartes, and all others that depend on the

same principle, we may remark, that if the planets be carried round the sun in vortices, the quantity of matter in the sun cannot affect the velocity of the vortex, or the bodies immersed in it; consequently the velocity might be the same though there were no central body whatsoever. The quantity of matter in the sun, therefore, cannot have the least effect in retaining the planets in their orbits. But the quantity of matter in the sun does affect the planet, and is a material element in its gravitation towards the centre of its orbit. It is therefore impossible that the action of a vortex, can have any effect whatever upon that gravitation. This argument is perfectly conclusive and fatal to the system of vortices. But we may observe that this system owed its downfall to another argument, equally if not still more powerful; viz. that whenever you suppose the vortex so arranged that it will explain one of those great facts in the planetary motions, known by the name of Kepler's Laws, it becomes quite inconsistent with the rest.

The vortices of Des Cartes have, therefore, ceased to afford any satisfaction even to the most superficial reasoner, and are now only known in the history of opinions; in which they will ever furnish a most instructive chapter.

HISTORY OF ASTRONOMY.

No science in the world is of more value, or of higher antiquity, than Astronomy. Its antiquity may be learned from what was spoken by God himself at the creation of the world; for he said—"Let the sun and the moon be for signs and for seasons," &c.

By this it is thought the human race never existed without some knowledge of astronomy among them. It is said by some Jewish Rabbins, that Adam was endowed with a knowledge of the nature, influence, and uses of the heavenly bodies; and Josephus ascribes to Seth and his posterity an extensive knowledge of astronomy.

It is supposed, by some writers, that Noah retired after the flood to the north-east part of Asia, where his descendants peopled the vast empire of China. "This," says Dr. Long, "may account for the Chinese having so early cultivated the study of astronomy." But the vanity of the Chinese has prompted them to pretend to a knowledge of this science almost as early as the flood itself.

To the emperor Hoang-ti, the grand-son of Noah, they attribute the discovery of the Pole star and the mariner's compass. They also say, that Confucius, their great philosopher, who lived 551 years B. C. has recorded 36 eclipses; but be this as it may, the Chinese are allowed to have had a very early knowledge of astronomy.

Some authors say it had its origin among the Chaldeans; others among the Hindoos, and some, with more probability, among the Egyptians. Professor Playfair has given a learned and ingenious dissertation on the astronomy of the Brahmins, in the second volume

of the Transactions of the Royal Society of Edinburgh, in which he shews the great accuracy and high antiquity of the science among them; and he also shews that it is extremely probable that the Hindoos were among the first astronomers in the world.

But Thales of Miletus is considered as the first person that propagated any truly scientific knowledge of astronomy; and it is said he acquired his knowledge of the subject in Egypt.

Thales taught his countrymen the cause of the inequality of the days and nights; explained to them the theory of eclipses, and the manner of predicting them; and gave them an example of his art in an eclipse of the sun, which happened soon after: he was born 640 years B. C. Anaximander was a pupil of Thales, and succeeded him as head of the school of Miletus. It is said he had some idea of the spherical shape of the earth; he is also said to have been the inventor of celestial globes, and of the orthographic projection of maps.

He erected a gnomon at Sparta, by which he ascertained the obliquity of the ecliptic, with the solstices and equinoxes.

Pythagoras was the next person who improved the science. He founded a school in Italy for that very purpose. Seconded by his earliest scholars, he clearly demonstrated the spherical shape of the earth, which Anaximander had only conjectured. Pythagoras taught that the sun was fixed in the centre of the planetary orbits, and that the earth moved round it with the other planets—the very system which is taught at this day. This opinion he communicated only to his pupils in secret; for being repugnant to the received opinions of that time, (and even appearances,) he did not wish to expose himself to the derision and persecution of ignorance and fanaticism, which would have been the inevitable consequence. For, about one hundred years after his time, Anaxagoras was condemned to banishment for saying that the sun was a mass of fiery matter. The measuring of time being a principal object in astronomy, many efforts were made by the ancients to determine accurately, and to compare with each other, the motions of the sun and moon, on which this measure universally depends.

Meton and Euctemon, two Greek astronomers, accordingly applied themselves to the study of this subject with great industry; and by sagaciously combining all the observations then known, formed a luni-solar period, or cycle of 19 years. This cycle was adopted on the 16th July, in the year 433 B. C. and is still in use. It is called the Metonic cycle, after the inventor of it. In this discovery is visible very extensive astronomical knowledge, and every appearance of great accuracy. Such was its success in Greece, that the order of the period was engraved in letters of gold, and at this day goes by the name of the Golden Number.

Among the ancients, Eudoxus is particularly distinguished for his knowledge, and also for his attention to astronomy. He built an observatory at Cnidus, his birth-place, which was shown long after his death. He invented a sphere, (which is called Eudoxus's sphere

to show the rising and setting of the sun and moon, &c. for the climate of Greece.

He also composed two books on astronomy: the one was a description of the constellations, the other treated on the times of their rising and setting. Aratus, by order of Antiochus, king of Macedon, reduced all that was then known of astronomy into Greek verse, anno B. C. 276. This poem is divided into two books, one of which describes the sphere of Eudoxus; the other gives rules for predicting the weather. Both of these have reached us entire.

While astronomy made such great progress in Greece, it was cultivated also by some of the Western nations of Europe. Pytheas, a celebrated astronomer at Marseilles, observed in that city the meridian altitude of the sun, at the time of the summer solstice, by a gnomon for the purpose of determining the latitude of that place. This man travelled to other parts of the globe, for the purpose of observing the phenomena of nature. He mentions having visited an island, which he calls Thule, where the sun rose presently after he had set. As this is the case in Norway and Iceland, it is inferred that he had reached those countries.

The same philosopher discovered that the Polar star is not precisely at the Pole itself. He likewise pointed out the connection of the tides with the motion of the moon.

Alexander the Great, by his conquests, rendered great service both to astronomy and natural philosophy. On these subjects Aristotle wrote, by his order, a great number of books. In one of these, entitled *De Cœlo*, he proves the spherical shape of the earth, from the circular shadow it casts on the moon in eclipses, and also from the difference of altitude observable on any of the fixed stars, in travelling north or south. He wrote one called *De Mundo*, which gives an account of the three quarters of the globe then known; viz. Asia, Africa, and Europe.

From this time, geography became, through its alliance with astronomy, a real science.

Horace mentions that the earth had been measured before his time; for he calls Archytas, who had been Plato's master, the measurer of the earth.

But the first person who measured the earth by a method consistent with the principles of geometry and astronomy, was Eratosthenes, librarian of the Alexandrian Museum. As this measurement was performed in a somewhat curious manner, it may be gratifying to the reader here to mention it, as it will serve to give some idea how that has lately been performed in Europe.

Eratosthenes was informed, that, on the day of the summer solstice, the sun was vertical at noon to the city of Syene, on the borders of Ethiopia, under the tropic of Cancer. A well is particularly mentioned to have been illuminated to the bottom by the sun at noon on the solstitial day. He knew likewise that Alexandria and Syene were both under the same meridian.

From these data, by means of a concave hemisphere, with a stile

fixed in its centre, he found that the shadow of the meridian sun caused by the stile at Alexandria, was one-fiftieth part of the whole circumferense. Hence he inferred, that the arc of the heavens comprised between Alexandria and Syene must be the same; and that the distance between the two cities must likewise be a similar arc, or one-fiftieth part of the circumference of the earth. On measuring this distance, he found it to be 5000 stadia, which gave 250,000 stadia for the circumference of the earth. As there were different stadia then in use, it is not well ascertained how many feet a stadium contained. If it was the Egyptian stadium that was used, this measurement exceeds the modern measures about a sixth part.

About the same time with Eratosthenes, flourished Aristarchus of Samos, who has given a very simple method of determining the ratio of the distance of the sun and moon from the earth, which, though not very accurate, is yet ingenious.

Of all the ancient astronomers, no one has so much enriched the science, or acquired so great a name, as Hipparchus, a native of Nice in Bithynia, 142 B. C.

One of his first cares was to rectify the year, which before his time was made to consist of 365 days six hours, which he found to be a little too much.* He also found that the sun was longer in traversing the six northern signs of the ecliptic than the other half of it; and deduced from this the eccentricity of the solar orbit.

He likewise made similar remarks and calculations for the lunar orbit.

From these data, he constructed tables of the motions of the sun and moon, which are the first of the kind that are mentioned.

Hipparchus made another important discovery. He found that the stars always preserved the same relative positions with respect to each other; but that they had all a trifling motion in the order of the signs of the zodiac, which was about 48″ in a year. He also substituted a more complete mode of measuring the ratio of the distance of the sun and moon from the earth, than the one given by Aristarchus. He made use chiefly of parallaxes; which is the method now in use. On the disappearance of a very large star, he set about numbering the stars, and to note down their configurations, respective distances, &c. and gave a very good catalogue of them.

This immense labour laid the foundation on which the whole superstructure of astronomy was to be raised. He was admired and celebrated in all nations where learning was pursued. Hipparchus was the first who applied this science to familiar purposes of the greatest utility in geography, by determining the situation of places by their latitudes and longitudes.

Cleomedes, who lived a little later than Hipparchus, has left a work on the sphere, the periods of the planets, their distances and magnitudes, with an account of ancient eclipses, which he says he derived the knowledge of from Pythagoras, Eratosthenes, and Hipparchus. This work is valuable, as it is the most ancient that has reached us on the subject.

The next person that claims particular notice, was Julius Cæsar, who rendered an important service to the science of astronomy by new-modelling the Roman calendar, B. C. 46 years.

Cæsar appears to have been well versed in astronomy. He discovered that autumn occupied the place of the winter months of the calendar, and that winter occurred in the mouths of spring. He invited the astronomer Sosigenes from Athens to Rome, to assist him in correcting this disorder. They began by giving fourteen months to the year of Rome, to re-establish the order of the seasons. They likewise determined that the year should consist of 365 days 6 hours in future; but, as we shall afterwards see, this was making the year too long by 11′ 11″; yet this was coming wonderfully near the real length of the tropical year, considering the state of the science at that time. This is still called the Julian year, out of compliment to Julius Cæsar.

Meneläus, a learned geometrician, A. D. 55, also distinguished himself in astronomy, by the discovery of the principal theorems of spherical trigonometry, which are applicable to the purposes of astronomy.

Astronomy had begun to languish in tne school of Alexandria, when the celebrated Ptolemy made his appearance, in A. D. 140.

He was a native of Pelusium in Egypt, and, when very young, came to Alexandria to study in that school. His principal work is entitled the *Almagest*, an Arabic word which signifies the *great collection*. It contains all the ancient observations and theories, to which his *own* researches are added, and is considered as the most complete collection of ancient astronomy that ever appeared.

Ptolemy embraced the common opinion, that the sun, moon, and planets moved round the earth as their common centre. This system continued to maintain its ground till the time of Copernicus, and has descended from Ptolemy to the present day, under the name of the Ptolemaic System.

Besides the Almagest, there exists another great work of Ptolemy's, his Geography, in which he determines the situation of places by their latitude and longitude, according to the method of Hipparchus. Ptolemy had the ambition, like Archimedes, to transmit the remembrance of his labours to posterity by a public monument. In the temple of Serapis, at Canopus, there is an inscription on marble, in which are explained the hypothesis of his astronomical system, such as the length of the year, the motions of the planets, &c. If there have been men of greater genius than Ptolemy, there is no man that ever collected a greater body of profound knowledge, or more truly conduced to the progress of astronomy, considering the age he lived in, and the time he wrote.

From Ptolemy to the time of the Arabs, no astronomer of the first order is to be found amongst the Greeks, except, perhaps, Theon of Alexandria, who wrote a learned commentary on the Almagest, about the year 395.

Among the Arabs there have been many excellent astronomers,

As there was no science to which they devoted so much attention, there were none in which they made so many discoveries. Their Caliphs were particularly distinguished for their knowledge and patronage of this science. They soon found that Ptolemy had stated the obliquity of the ecliptic a little too great; and, after many observations, found it to be nearly what it is at present.

The Caliph Almansor the Victorious, who ascended the throne in 754, ranks among the first of their astronomers. Haroun, his grandson, who reigned from 786 to 809, sent a present to Charlemagne of a water clock, in the dial of which were twelve small doors, forming the division of the hours. Each of these doors opened at the hour it marked, and let out little balls, which, falling on a bell of brass, struck the hours. The doors continued open till 12 o'clock, when twelve little knights, mounted on horseback, came out together, paraded round the dial, and shut all the doors. This clock at that time astonished all Europe.

After Haroun, his son Al Maimon succeeded to the throne. He also cultivated the study of astronomy. In his time there lived several celebrated astronomers, among whom was Alfragan, who composed several books on astronomy; and from his facility in calculation, he was surnamed the Calculator.

Albatégni was also among the greatest of the Arabian astronomers. He found the year to contain only two minutes less then what it was found to be by Dr. Halley six hundred years after.

After the Arabs had conquered the greater part of Spain, in the year 1020, they built there many observatories to conduct their observations. Alhazen, one of their astronomers, has left a treatise on Optics, which contains the first established theory of refraction and twilight which we have.

Among the Persians, also, there have been many eminent astronomers. They made many observations to discover the real length of the solar year, which they fixed at 365 days six hours. One of their chief astronomers was the famous Ulugh Beg, grandson of Tamerlane; he not only encouraged the sciences as a sovereign, but was himself reckoned one of the most learned men of his age. To determine the latitude of Samarcand, it is said he employed a quadrant, the radius of which was one hundred and eighty feet!*

He composed a catalogue of the stars, and several astronomical tables, the most perfect then known in the east. He was assassinated by his own son.

From the year 800 till the beginning of the fourteenth century, almost all Europe was immersed in gross ignorance. The only people who paid any regard to science, was the Arabs that settled in Spain, some of whom have been mentioned above. Profiting by the books they had preserved from the wreck of the Alexandrian

* It is thought by many astronomers, that this must have been a gnomon instead of a quadrant.

library, they cultivated and improved *all* the sciences, and particularly astronomy, in which they had many able professors.

From the beginning of the ninth century to the year 1423, when Purbachius appeared, there is no name that deserves to be mentioned as contributing to the improvement of astronomy. Purbachius was a man af great talents; he began an Epitome of Ptolemy's Almagest, but died before it was completed. This was executed by his friend and pupil, John Muller, commonly called Regiomontanus. This man made many observations, and collected the writings of many of the ancient astronomers. He published ephemerides for thirty years to come, wrote a theory of the planets and comets, and calculated a table of signs and tangents for every degree and minute of the quadrant. He died in the year 1476.

Nicolas Copernicus, born 1473, rose next, and made so great a figure in astronomy, that the true system discovered, or rather restored by him, has been ever since called the Copernican System. He revived the old system of astronomy taught by Pythagoras, which had been set aside from the time of Ptolemy. His understanding at once revolted against the explanations which that philosopher had given of the motions of our planetary system; and set about correcting his mistakes, by laying the foundation of what is at this day held to be the true system of the world. This system he gradually improved by a long series of observations, and a close attention to the writings of ancient authors. His first grand work was printed in 1543, under the care of Schoner and Osiander; and he received a copy of it only a few hours before his death, on the 23d May, 1543, at the age of seventy years.

After the death of this great man, there were several astronomers of considerable note, that greatly improved the science; but the only one that claims particular notice was Tycho Brahe, a Danish nobleman, who was the inventor of a new system, a kind of semi-Ptolemaic, which he vainly endeavoured to establish instead of the Copernican. His numerous works shew that he was a man of great abilities; and it is to be regretted that he sacrificed his talents, and perhaps his inward conviction, to superstitious considerations. He restored the earth to its fancied immobility, and made the sun and moon revolve round it; but the planets he made to revolve round the sun, which was a still more absurd hypothesis than that of Ptolemy. But we ought to forgive this error, or rather weakness, in return for the many observations and discoveries with which he enriched astronomy. No man ever made more observations than Tycho Brahe.

Contemporary with Tycho flourished several eminent astronomers, among whom was the famous Kepler. To him we owe the true figure of the orbits of the planets, and the proportions of the motions and distances of the various bodies which compose the solar system. The three great Laws of Kepler may be said to be the foundation of all astronomy. Kepler was born in 1571, and died in 1631.

Galileo was the next person who rendered any very important services to astronomy. He was the first who applied the telescope

to astronomical observations, and with it made many useful and valuable discoveries. By the observations and reasoning of Galileo, the system of Copernicus acquired a probability almost equivalent to demonstration. By espousing the opinions of Copernicus, he drew on him the vengeance of the Inquisition, who decreed that he should pass his days in a dungeon; but he was liberated after the expiration of a year, on condition that he should never more teach or hold up the Copernican as the true system of astronomy. He was born in the year 1564, and died in 1642.

In spite of the Inquisition, or the passages in Scripture which were always brought forward as objections to the motion of the earth, the system of Copernicus gained ground every day.

Contemporary with Galileo were a number of astronomers, who contributed to the progress of the science. Baron Napier published his tables of logarithms in 1614. Bayer, also, obtaining great celebrity by the publication of his *Uranometria*, in which the stars were designated by the letters of the Greek alphabet, which is still the case on our celestial globes and planispheres.

Gassendi, a French philosopher, saw the planet Mercury on the sun's disc, which was the first observation of the kind. A little after this, in the year 1633, Mr. Horrox, an Englishman of very extraordinary talents, discovered that Venus would pass over the disc of the sun on the 24th November, 1639. This event he only mentioned to one friend, a Mr. Crabtree; and these two men were the *only persons* in the world who observed this transit, which was the first transit of Venus that had ever been viewed by human eyes. Mr. Horrox made many useful observations about this time, and had even formed a new theory of the moon, so ingenious as to attract the attention of Sir Isaac Newton. But the hopes of astronomers, from the abilities of this extraordinary young man, were soon blasted, for he died in the beginning of the year 1640, aged twenty-four years.

Hevelius, burgomaster of Dantzic, also rendered himself eminent by his numerous and delicate observations. He founded an observatory at Dantzic, and furnished it with a great many excellent instruments, some of which were divided into so small divisions as 5′. His observations on the spots of the sun, and on the nature of comets, were very numerous; and his catalogue of fixed stars, containing the longitude of above 1888, was remarkable for its accuracy. It is to him, also, we are indebted for the first accurate description of the spots on the moon.

The improvement of the telescope continued to lay open new sources of discovery. The celebrated Huygens constructed two excellent telescopes, one of twelve feet in length, and the other twenty-four, with which he discovered the fourth satellite of Saturn; which he said afterwards led him to discover the *ring* that surrounds that planet. Huygens was likewise the first person who applied pendulums to clocks. He died in 1695, aged 66 years.

About this time the Royal Society of London, and the Royal Academy of Paris, were established, each of which has produced

astronomers of the first order. The first person appointed to conduct the observations at the royal observatory at Paris, was Dominic Cassini, who soon after discovered the first, second, third, and fifth satellites of Saturn. He also discovered that the planets Jupiter, Mars, and Venus, turned round their axis in a manner similar to the earth. He died in the year 1712.

The successive propagation of light, one of the most curious discoveries in astronomy, was about this time made by Roemer, a Danish astronomer. This has ever since been accounted a most essential element in astronomy, and must secure immortality to the name of Roemer.

England, at all times, produced astronomers of the first order; and at this period it had to boast of Hook, Flamstead, and Halley.

Hook was born in 1635, and died in 1702. He was not only a great observer in every branch of astronomy, but his inventive powers have been exhibited in almost every branch of science. He was the inventor of the Zenith Sector, an instrument which was used to determine whether or not the earth's orbit had any sensible parallax. He gave the first hint of making a quadrant for measuring angles by reflexion; and he, in some measure, anticipated the discoveries of Newton, by shewing that the motion of the planets resulted from a projectile force, combined with the attractive power of the sun.

Flamstead was born 1646, and died in 1720. After the Royal Observatory at Greenwich was finished, he was appointed by King Charles II. to the management of it, with the title of Astronomer Royal. He made a very great number of observations, which he has recorded in his *Historia Celestis,* and in the Philosophical Transactions. But the principal service he rendered astronomy, was by forming a catalogue of 3000 fixed stars.

Flamstead was succeeded, in 1719, by Dr. Halley, the greatest astronomer, says M. de la Lande, in England; and Dr. Long adds, "I believe he might have said the whole world." He was sent by King Charles II. to St. Helena, in order to form a catalogue of the stars in the southern hemisphere, which was published in 1679. While he was in the island of St. Helena, making this catalogue, he had an opportunity of observing a transit of Mercury across the sun's disc, by which he was enabled to point out the method of determining the parallax of the sun.

On his way between Calais and Paris, he obtained a sight of the famous comet that appeared in 1680, which suggested to him the idea of writing a treatise on the subject of comets, in which he investigates the orbits of these wandering bodies, and predicted the return of the one that appeared in 1759, which is the only prediction of the kind that ever was verified. It is said that during the nine years he was at Greenwich, he made 1600 observations. Halley was acquainted, either personally or by letter, with every astronomer of note in Europe then living. He died in the year 1742, aged eighty-six years; and was succeeded by Dr. Bradley, to whom we are indebted for two of the most beautiful discoveries of which the science can boast—the

aberration of light, and the nutation of the earth's axis. He also made a great many observations, in order to discover if the fixed stars had any sensible parallax. These observations are partly published, and the remainder of them are in the hands of a Mr. Abraham Robertson, to whom their publication was entrusted. Bradley died in the year 1762.

But to no individual is the science of astronomy more indebted than to the celebrated Sir Isaac Newton. This great man was born on the 25th December, 1642, at Woolstrope in Lincolnshire. His discoveries were not confined to astronomy alone; for in mathematics and natural philosophy he was equally great. His chief discovery in astronomy was the law of gravitation, by which he was enabled to account for some of the greatest phenomena in nature. His great work the Principia, appeared in 1686. This work is one of the most valuable books on physical astronomy that ever was published. His discoveries are so numerous and important in this science, that the solar system, or that restored by Copernicus, has received the appellation of the Newtonian system.

In this country there have been several distinguished astronomers since the time of Newton, among whom may be mentioned Dr. Long, Dr. Keil, Dr. Bliss, Mr. Ferguson, Mr. Hadley, and Dr. Herschel; the latter of whom, for his many accurate observations, deserves to be ranked among the first class of astronomers of any age or nation. In the year 1781, on the 13th of September, he discovered the planet Georgium Sidus. In the year 1787, he discovered two satellites revolving round that planet; and in 1790 and 1794, he discovered other two satellites. These discoveries of Herschel form a new era in Astronomy.

Dr. Maskelyne, the late Astronomer Royal, has likewise rendered very important service to the science. He was the first who proposed to the Board of Longitude the publishing of an Ephemeris or Nautical Almanack, which was begun in the year 1767. This almanack is still continued annually, and has been of the utmost service to navigation.

Dr. Maskelyne died a few years ago, and was succeeded by the present Astronomer Royal, Mr. Pond, who is also a man of genius, and promises to be of great service to astronomy.

On the continent also there have been many astronomers of great talents since the time of Newton, particularly in France. Among these, La Caille deserves to be mentioned with credit. He was born in 1713, and in the year 1751 he undertook a voyage to the Cape of Good Hope, for the purpose of perfecting the catalogue of the stars in the southern hemisphere. After incredible labour and exertion, he returned to Europe with a catalogue of 9800 stars, which were comprehended between the south pole and the tropic of Capricorn. In addition to these labours, La Caille calculated new tables of the Sun, made observations on the parallax of Mars and Venus, on atmospherical refraction, on the length of pendulums, and measured a degree of the meridian during his stay at the Cape: he died in the

year 1762. Contemporary with La Caille lived several very eminent astronomers, of whom may be mentioned Cassini, Bouguer, Condamine, Maupertuis, and Clairaut, who were all employed soon after this, in measuring degrees of the meridian in different parts of the world. Professor Mayer, of Gottingen, deserves also to be mentioned, as contributing greatly to the improvement of the science, by the excellent set of tables which he calculated for finding the place of the moon, &c. These tables are now used in making the calculations of the Nautical Almanack. His widow received 3000*l*. for them from the British Government, on account of their great accuracy. Mayer died in 1762, aged 41 years. D'Alembert also rendered great service to astronomy by his indefatigable labours, particularly in resolving the problem of the precession of the equinoxes. He died 1783.

Euler, one of the greatest geniuses and calculators that any age or nation can boast of, ought to be associated with the history of astronomy, as one of its most distinguished votaries and improvers. By his many and accurate calculations, he has rendered the most essential service, not only to astronomy, but to all the physical sciences; but his labours are too numerous to be detailed here. The eighteenth century was distinguished by many other eminent astronomers; viz. Maclaurin, Simpson, Bernoulli, Lambert, Mason, Boscovich, De Lisle, Bailly, La Lande, &c.

The celebrated La Grange, who outlived most of his contemporaries, was born at Turin in 1736, and has enriched astronomy with some of the most splendid discoveries of which it can boast. The subjects of his researches in this science were, the theory of Jupiter's satellites, the motions of the planets, and their action on each other, which he determined with great accuracy.

As the labours of the most distinguished astronomers that have appeared in the world have now been briefly noticed, and of whom their labours are the only memorials that exist; all that remains to complete this short account of the improvements that have taken place in the science, down to the present day is to mention the labours of a few individuals still alive.

La Place has also distinguished himself by his labours to improve astronomy, particularly in solving the problem of the tides, in adding some new corrections to the lunar tables, and some discoveries respecting the precession of the equinoxes. He also ascertained the mean depth of the sea to be four leagues.

The name of Troughton ought also to be mentioned; for to no individual of the present age is *practical astronomy* more indebted than to this distinguished artist. The great improvements he has made upon astronomical instruments, has rendered his name celebrated in every country in Europe. There is scarcely an observatory of note to be found that does not contain some of Mr. Troughton's instruments.

The labours of Dr. Olbers, Harding, and Piazzi, will be noticed in treating of the new planets.

SUPPLEMENT

TO

ASTRONOMY

AS IT IS, COMPARED WITH WHAT IT WAS;

CONTAINING,

THE USE OF ASTRONOMICAL INSTRUMENTS,

THE

Method of computing the Notes of the Calendar,

THE MAGNITUDES, PERIODS, AND DISTANCES OF THE SUN, MOON PLANETS, &c.

INTRODUCTION.

THE Work, to which the following pages form a Supplement, being entirely confined to what may be termed the *Descriptive* and *Historical* parts of Astronomy, it was thought it might tend to make the work still more generally useful if it contained a description of Astronomical Instruments, and a short account of the Calendar. In order to accomplish this, without interfering with the plan proposed for treating of the various branches of Astronomy in a systematic and popular manner, it was found that a Supplement was necessary. This has therefore been added, and will be found to form a very valuable addition to the Work itself.

The principal instruments used in the practical part of Astronomy are not only represented by figures and described at considerable length, but many other subjects connected

with Astronomy have been introduced, which could not have been noticed in a work purely astronomical. Among these will be found several interesting essays on Meteorology and Physical Geography, accompanied with diagrams, which cannot fail to render the subjects perfectly level to the understanding of the humblest inquirer after scientific information.

An acquaintance with the Calendar, and the manner of computing the common Notes of the year, is so useful to every class of society, that the rules contained in the following pages, for effecting this, cannot fail to gratify all who wish to possess the slightest acquaintance with Astronomy.

The manner of calculating most of the fundamental *Elements* employed in Practical Astronomy have been added, with the view of rendering the work not only more complete, but to induce the astronomical reader to enter more deeply into this beautiful and highly interesting branch of the science. To those who have made some progress in the study of Astronomy, and who are in some degree judges of works which treat of the practical parts of the science, this will perhaps be considered the most valuable part of the Work.

ASTRONOMY,

AS IT IS KNOWN AT THE PRESENT DAY.

Miscellaneous Subjects.

On Astronomical Tables.

In constructing tables for computing, at any given instant, the places of the sun, moon, and planets, the first step is to determine, from a series of accurate observations, the time in which those bodies describe a space of 360°, or perform a complete revolution round the sun, or the primary planet.

When this important element is exactly ascertained, we can easily find, by simple proportion, the space which the planet describes in any number of years, months, days, minutes, or seconds, upon the supposition that it moves uniformly, or describes equal spaces in equal times in the circumference of a circle. This is called the *mean motion* of the body.

The next thing to be settled is the epochs, or radical places of the planet, which is nothing more than its longitude upon the supposition of its motion being uniform, at certain epochs of time, from which the calculations are supposed to commence. These epochs of time, or mean longitudes, are generally put down in Astronomical tables of the noon of the 1st of January of each year. These elements are all which would be necessary for computing the longitude of a planet, if it moved uniformly in a circular orbit; but as all the bodies of the solar system move in eliptical orbits round the sun, or their primary planet, placed in one of their foci, we must next determine the form of their orbits, or the nature of the elipse which they describe. This may be done in the case of the sun and moon, by observing the variations of their apparent diameters during a complete revolution; their distance from the earth being inversely proportional to the angle they subtend.

The ratio of their greatest and least diameters is a measure of the relation between their greatest and least distances, and consequently enables us to ascertain the eccentricity of their orbits. The same results may be obtained by observing the spaces described by the planets during equal intervals of time. As the areas described by the radius vector of a planet are proportional to the times, equal areas will correspond to equal angles, if the planet moves in a circular orbit. The observed inequalities, therefore, in the case of an eliptic orbit, being the effect of the eccentricity of the orbit, will

enable us to determine that important element. If we therefore, suppose that the real planet moves with different velocities in an eliptical orbit, while a fictitious planet sets off from the *peregee* at the same instant, and describes a circular orbit, with an uniform motion, in the same time that the real planet describes the eliptical orbit, we shall obtain a simple explanation of the inequalities arising from the eliptical motion of the body. At no place of the orbit will these two planets be together, but when they are in *Peregee* and Apogee, or when the real planet is at its greatest and least distances from the sun.

The angular distance, at any time, between the real and fictitious planet, is called the *Equation of the Centre.*

This is greatest when the fictitious planet is at that part of its orbit, where a line drawn from it to the line of the *Apsides* forms a right angle, or where the real planet is at its mean distance. From the *Perihelion* to the *Aphelion*, the real planet will be *before* the fictitious; but from its Aphelion to its Perihelion, it will be *behind* the fictitious planet. During the motion of the real planet from the Aphelion to its Perihelion, the mean place has been farther advanced than the true place; and therefore the equation of the centre must be subtracted from the mean longitude, to obtain the true longitude of the planet; but from the Perihelion to the Aphelion it must be added, because the mean place is behind the true. The equation of the centre obviously depends on the mean anomaly of the planet, or its distance from the *apogee*, which, in all the primary planets except Venus, has a motion according to the order of the signs. By determining, therefore, the place of the *apogee*, and subtracting its longitude from that of the planet, we obtain the *mean anomaly* of the planet; with which, as an *argument*, we find from the Tables the corresponding equation of the centre, which, applied to the mean place of the planet, gives its longitude in an eliptical orbit.

This result would be the true place of the planet in its orbit, if its motion were not influenced by any disturbing force; but, owing to the mutual action of the planets, their motions are sometimes accelerated, and at others retarded; and therefore the longitudes of these bodies must be still farther corrected.

In determining the places of the planets, we must compute also their latitudes or distances from the ecliptic, which must evidently depend on the distance of the planet from its *node*. As the nodes of all the planetary orbits have a retrograde motion along the ecliptic, the radical place of the node, or its position at any particular time, must first be ascertained; and its retrograde motion being known, we can obtain the longitude of the node at any time, and consequently the distance of the planet from the node. When the distance from the node is 0, the latitude will be nothing; and when the distance from the node is a *maximum*, or 3 or 9 signs, the latitude is also a maximum, or equal to the inclination of the planet's orbit to the ecliptic.

The places of the primary planets computed in the manner which is here described, are evidently their *heliocentric* places, or their places as seen from the sun. The *geocentric* place of the planet, or

its place as seen from the earth, may be readily found by the solution of a triangle, formed by lines joining the sun and planet, the sun and earth, and the planet and the earth. The angle at the sun is equal to the difference between the heliocentric longitude of the earth and the planet. One of the sides of the triangle is equal to the distance of the earth from the sun, and the other is equal to the distance of the planet from the sun; so that from these *data*, the angle formed at the sun, or the difference between the geocentric place of the sun, and the geocentric place of the planet, may be easily obtained; or we may obtain the angle formed at the planet, which is the difference between its heliocentric and geocentric place.

On the Changes that have happened in the relative situation of Double Stars.

THE late Sir W. Herschel remarks, that the affections of the newly-discovered celestial bodies extend our knowledge of the construction of the solar system, which is the one best known to us; and proceeds to support, by the evidence of observation, the opinion, which he has before advanced, of the existence of binary sidereal combinations, revolving round the common centre of gravity. Dr. Herschel first considers the apparent effect of the motion of either of the three bodies concerned, the two stars, and the sun with its attendant planets; and then states the arguments respecting the motions of a few only out of the fifty double stars, of which he has ascertained the revolutions. The first example is Castor, or Alpha Geminorum: here Dr. Herschel stops to show how accurately the apparent diameter of a star, viewed with a constant magnifying power, may be assumed as a measure of small angular distances; he found that ten different mirrors, of seven feet focal length, exhibited no perceptible difference in this respect. In the case of Castor, no change of the distance of the stars has been observed, but their angular situation appears to have varied somewhat more than 45° since it was observed by Dr. Bradley in 1759; and they have been found by Dr. Herschel in intermediate positions at intermediate times. Dr. Herschel allows that it is barely possible that a separate proper motion, in each of the stars and in the sun, may have caused such a change in the relative situation, but that the probability is very decidedly in favour of the existence of a revolution. Its period must be a little more than 342 years, and its plane nearly perpendicular to the direction of the sun. The revolution of *Gamma Leonis* is supposed to be in a plane considerably inclined to the line in which we view it, and to be performed in about 1200 years. Both these revolutions are retrograde; that of Epsilon Bootis is direct, and is supposed to occupy 1681 years, the orbit being in an oblique position with respect to the sun. In Zeta Herculis, Dr. Herschel observed, in 1802, the appearance of an occultation of the small star by the larger one; in 1782 he had seen them separate; the plane of the revolution must therefore pass nearly through the sun; and this is all

that can at present be determined respecting it. The stars of Delta Serpentis appear to perform a retrograde revolution in about 375 years: their apparent distance is invariable, as well as that of the two stars which constitute Gamma Virginis, the last double star which Dr. Herschel mentions in this paper, and to which he attributes a periodical revolution of about 708 years.

On the great Coronæ, or Circles which sometimes surround the Sun and Moon.

As it may be satisfactory to some of our readers to know the opinion of so celebrated a Meteorologist as Mariotte on the cause of the circular ring which sometimes appears round the sun and moon, we shall present them with the following extract from his work on Colours:

"Sometimes, when the air is pretty serene, a circle of about 45° diameter is seen round the sun or moon; the colours are not in general very lively, the blue is without, and the red within; their breadth is nearly as in the common external rainbow.

"Explanation. I take for the cause of this appearance small filaments of snow, moderately transparent, having the form of an equilateral triangular prism. I conjecture that the small flat flakes of snow which fall during a hard frost, and which have the figure of stars, are composed of little filaments like equilateral prisms, particularly those which are like fern leaves, as is easily seen by the microscope. I have often looked at the filaments which compose the hoar frost, that appears like little trees or plants in the cold mornings of spring and autumn, and I have found them cut into three equal facets; and when viewed in the sunshine, they exhibited rainbow colours. Now it is very propable that, before these little figures of trees or stars are formed, there are floating among the thin vapours in the air some of these separate prisms, which, when they unite, form the compound figures. These little stars are very thin, and very light, and the little filaments, which compose them, are still more so, and may often be supported a long time in the air by the winds: hence when the air is moderately filled with them, so as not to be much darkened, many of them, whether separate or united, will turn in every direction as the air impels them, and will be disposed to transmit to the eye for some time a coloured light, nearly like to that which would be produced by equilateral prisms of glass."

On Meteoric Stones.

It had long been conjectured by several persons in this country, that the stones said to have fallen from the air, on different parts of the earth, and lately analysed by Mr. Howard, might originally have been emitted by lunar volcanos facing the earth; and meeting with little or no resistance from the moon's atmosphere, might have risen to such a height, as to be more powerfully attracted by the earth than

by the moon, and, of consequence, to be compelled to continue their course, until they arrived at the confines of our atmosphere, and were again retarded by its resistance.

The idea has been lately renewed in France by Laplace; and the inflammation and combustion of the stones has been attributed to the intense heat which must necessarily be extricated by so great a compression of the air, as would be produced by the velocity with which these bodies must enter the atmosphere.

Mr. Biot has calculated, that an initial velocity, about five times as great as that which a cannon ball sometimes receives, would be sufficient for the projection of a body from a lunar volcano into the limits of the earth's superior attraction, which are situated at nearly one-ninth of the distance of the earth from the moon.

A body, entering the atmosphere with such a velocity, would soon experience a resistance many thousand times greater than its weight, and the velocity would therefore soon be very considerably lessened. It may easily be shown, that a stone of moderate dimensions could scarcely retain a velocity of above 200 feet in a second. With respect, however, to the actual probability of the stones in question having been projected from the volcanos of the moon, there will, perhaps, long be a diversity of opinion; and, in the absence of all accurate knowledge on the subject, it would, perhaps, be unphilosophical to attempt to establish any theory respecting their origin.

Upon the Precision to be attained with Astronomical Instruments.

Mr. Amici, in a letter addressed to Baron Zach, affirms, that, on a circle of 3 feet, one cannot, even with the aid of a vernier and simple microscope, discern two or three seconds, even though the instrument be mathematically divided with the utmost precision.— "To prove this," says he, "I draw upon a sheet of white paper two thick vertical lines of $\frac{1}{12}$ an inch, in such a manner, that the right side of one is parallel with the left of the other. These two lines may be considered as belonging, one to the limb of the instrument, and the other to the vernier. I place this paper in a very strong light, and I raise myself perpendicularly from it to the distance of 28 feet; I look at these lines with one eye, and I see them united as though there were but one line. Here then is the utmost extent of my sight, at which I judge the lines to be joined, although in reality there is a distance equal to their own length between them. This limit expressed by the angle formed by the object in the eye of the observer answers to 51 seconds; but in a circle of 3 feet in diameter, the arc of a second occupies 0·001 of a line; and this arc forms in the eye of an observer, furnished with a simple microscope, of an inch focus, an angle of 17 seconds, consequently invisible to me."

Mr. Amici closes his letter by remarking, that no astonishment ought to be excited at the inaccuracies to which the most experienced astronomers are subject, making a difference of from 1 to 5 seconds

if due attention be paid to the errors which are likely to result from the optical parallax between the divisions of the limb and those of the vernier, the inequalities of the lines which form those divisions rendering their union equivocal and doubtful, the reflexion of the glasses; the unequal expansion of the metal; and the irregularity of the *surface or levels.*

Upon the apparent Size of Objects caused by the Refraction of Light in passing through the Atmosphere. By JEAN MILE, Professor of Physiology.

THE author, in a letter addressed to Mr. J. C Skrodzki, Professor of Physic at Varsovie, recalls to his recollection, that, after having gone through the explanation of this well-known phenomenon, they were mutually convinced of their insufficiency. He therefore proposes an explanation founded upon the refraction of light, which enables us to perceive objects situated beyond the limits of our atmosphere. This refraction not only enables us to see objects in a situation different from their real position, but it also changes their real size. This latter effect resembles the former in this, that the nearer the objects are to the horizon, the greater is their apparent size; or, what amounts to the same thing, the greater their distance from the zenith, so in proportion is their size The rays of light which traverse the air through a denser medium than itself, terminated by plane or parallel surfaces, follow, in issuing from the latter, a direction parallel to their incidence. But it has been falsely concluded in this case, that the object is seen under the same angle as though the rays had only passed through one medium. The author affords us eight successive theorems, which he links with each other, and the last of which explains the phenomenon of the apparent size of objects.

Theorem 1st.—An object and the observer being situated in the air, should the visual rays which pass from the one to the other traverse an intermediate medium, terminated by plane surfaces, the visual angle will become greater.

He gives a demonstration of this upon mathematical principles, which would be too long to be inserted here. The following experiment, however, will render his axiom perfectly comprehensible. Procure a tin tube, three inches in diameter, and a yard in length, the two ends of which must be closed with plain glass. The tube is then to be placed in a horizontal position, and half filled with spirits of wine, that is to say, to its central axis; and if an object then be viewed through the tube, that half of the object which is seen through the medium of the spirits of wine will appear to be much larger than the half seen through the air alone. In general, the degree of augmentation is in a direct ratio to the depth of the refracting medium, and consequently depends in this instance upon the length of the tube.

Theorem 2d.—The visual angle will never change, so long as the rays from the surfaces are spherical; and their radii will be respec-

tively equal to the distance of the eye to each of them; in fact, the eye being situate at the centre of the curves which terminate the medium, the visual rays proceeding in the same direction will not be subject to the slightest deviation. The object then will be seen under the same angle. This may be proved by the following experiment. A conical shaped tube of tin may be half filled with spirits of wine, as mentioned above, and each end enclosed with watch glasses of different diameters, and then placing the eye in the direct centre of the two spherical surfaces in the front of the tube.

Theorem 3d.—The visual angle will become smaller when the radii from the surfaces are spherical, and are respectively smaller according to the distances of the eye from them. This may be easily proved by the above-mentioned apparatus, by placing the eye at a greater distance from the central point of the termination of the two spherical surfaces.

Theorem 4th—Is the converse of the preceding one; that is to say, the visual angle is greater when the radii from the surfaces, are spherical, which terminate the refracting medium, and are respectively greater than the distance between the eye and each of them. This is also to be proved by the before-mentioned apparatus, by placing the eye at a less distance from the tube than that between its centre and the termination of its spherical surfaces.

Observation.—Should the medium in which the eye is situated be of greater density, the refraction will occasion phenomena directly the contrary. This is the case with the objects placed beyond the limits of our atmosphere.

Theorem 5th.—The surfaces of the refracting medium being spherical, and their radii being equal to the distance of the eye from each of them, the visual angle will not be changed. This would be the case were the eye situated at the centre of the earth, which is physically impossible.

Theorem 6th.—If the distance of the eye be greater than the radius of the surface of the refracting medium, the visual angle will become greater. This would be the case were an observer situated in such a manner that the centre of the earth intervened between him and the celestial bodies, which is physically impossible.

Theorem 7th.—If the distance of the eye be less than the radius of the refracting surfaces, the visual angle would be less. This is what always takes place, at least, when we look at the celestial bodies

Theorem 8th.—Although the heavenly bodies ought to appear much smaller when seen from the surface of the earth, owing to the refraction of light, still the degree of diminution of the visual angle depends upon the greater or less extent of the refracting medium, that is, the atmosphere;—the diminution of the visual angle, therefore, is less according as these limits are more extended. Hence it results, that the heavenly bodies appear to us so much the larger, in proportion as the limits of the atmosphere are extended. These bodies, therefore, will increase in size in proportion to the increase of their distance from the zenith; for the nearer they approach the horizon, the more extensive are the limits of the atmosphere, though

the observer must behold them when he is situated upon the surface of the earth. We may hence perceive the reasons why, when the sun is invisible, the densest clouds appear to be at the horizon; why the clouds which are driven by the wind towards the zenith decrease in magnitude the higher they rise why, when the sun is momentarily hid by the clouds, the rays appear to accumulate at the point where he is situated, although, in reality, they are parallel to one another. The explanation of the beautiful phenomenon of the Aurora Borealis is capable also of receiving a slight modification.

Upon the Meteors which play round the Earth.

PROFESSOR MEINECKE, in a paper read to the Society of Natural History at Halle, in Germany, proves, in various ways, the existence of an inferior or subterrestial atmosphere. He considers himself borne out by reasons, which he alleges to conclude with certainty, that an atmosphere which can penetrate to the depth of 20 geographical miles is already compressed at a less depth, to a degree at which, without being liquid, forms a fluid equivalent to water. Hence there results to the interior parts of the earth an atmosphere, in comparison with which the common atmosphere will appear to be of a very light description, which, as is known, is equal to a column of water 30 feet high, or thereabouts.

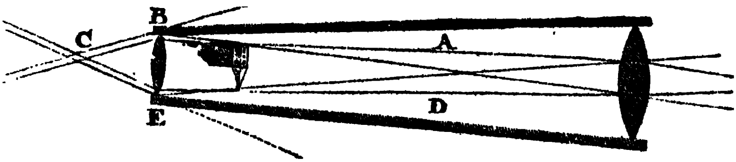
It is to this mass of interior air, which pervades the pores of fossils, exists in the cavities and abysses of the earth, and forms likewise a portion of the elementary parts of fossils, that Professor Meinecke attributes the greater part of meteors; while the mass of light air universally disseminated in the form of a vapour, and which is called atmosphere, contributes but in a very small degree to their appearance. As he attributes the barometrical phenomena to the subterrestial atmosphere, he denies at the same time the influence of the moon upon the weather.

On the Change of the Place of the Fixed Stars.

IT appears from a paper by Mr. Pond, Astronomer Royal, lately read before the Royal Society, that he thinks that his observations lead to the conclusion that some variation, either continued or periodical, takes place in the siderial system, which, producing but very small deviations in a finite portion of time, has hitherto escaped *notice*. The nature of this motion appears to be such, that the stars are now mostly found a considerable quantity to the *southward* of their computed places. With respect to the *laws* by which these motions are governed, Mr. Pond admits that his observations are not sufficiently exact to throw any light upon the subject.

Astronomical Telescope.

THE Astronomical Telescope which was invented by Kepler is represented by the following figure.



It consists of two convex glasses placed in a tube; the one next the object is called the object-glass, and the one next the eye, as B E, the eye-glass, which is always of a much less focal length than the object-glass. The focal length of the object-glass is a little greater than the tube into which it is screwed, and the eye-glass is fixed into a small tube, which can be moved out and in at the other extremity of the longer tube. When such an instrument is directed to a distant object, and distinct vision obtained by adjusting the tube containing the eye-glass, the magnified object is formed by the rays A B C and D E C, which come from the extremities of the visible field through the middle of the object-glass, and produce an inverted image nearly in the principal focus of the eye-glass, through which this image is viewed as by a simple microscope, and therefore still remains apparently inverted. This, however is not considered a disadvantage by astronomers, and therefore it has received the name of the *astronomical telescope.*

In order to find the magnifying power, we must divide the focal length of the object-glass by that of the eye-glass: this quotient is consequently the greater as the focal length of the object-glass is greater, and as that of the eye-glass is smaller; but the power of the instrument cannot be increased at pleasure by lessening the focal length of the eye-glass, because the object-glass would not furnish light enough to render the view distinct, if the magnifying power were too great.

Galilean Telescope.

The Galilean Telescope received its name from its having been first used by Galileo, and differs in no respect from the astronomical telescope, excepting in the substitution of a concave eye-glass in place of a convex eye-glass. This eye-glass is placed between the object-glass and its principal focus, and receives the converging rays before they form the image.

The magnifying power of this telescope will be equal to the focal length of the object-glass divided by that of the eye-glass: for the extreme pencils which were formerly made to converge, are now made to diverge.

This telescope possesses some advantages over the astronomical telescope. 1st. It has the same magnifying power under a shorter length, the length of the telescope being equal to the difference of the focal lengths of the object-glass and the eye-glass, whereas in the astronomical telescope it is equal to their sum. 2d. It gives us an erect view of the object without using three eye-glasses, which must occasion a great loss of light, even if the lenses are ground to a perfect figure. 3d. There is less absorption of light, in consequence of the rays passing through a less thickness of eye-glass; and 4th, the vision is much more perfect; a circumstance which no doubt arises from the rays never coming to a positive focus, and never crossing one another in a condensed state during the whole of their progress through the instrument. For it cannot be doubted that the rays of light, notwithstanding their extreme tenuity, interfere with one another, and produce an indistinctness of vision.

The disadvantages of the Galilean telescope arise solely from its limited field of view since the lateral pencils now diverge from the axis of the lenses, the field of view depends solely on the diameter of the pupil of the eye, and as this cannot be increased at pleasure, there are no means of remedying this evil in the Galilean telescope.

The imperfections of the common refracting telescope with a single object-glass, are so great, that in order to obtain a high magnifying power, it is necessary to use object glasses of a great focal length, such as those of Huygens, some of which were not less than 24 feet in length.*

It follows from the theory of aberration, arising from the spherical figure of the surface, that the apparent indistinctness of a given object seen through a refracting telescope, is directly as the area of the object-glass, and inversely as the square of the focal distance of the eye-glass. In like manner, it may be shown, that the apparent brightness of a given object is directly as the square of the lineal aperture of the object-glass, and inversely as the square of its magnifying power. Hence, it follows, that in refracting telescopes of different lengths, a given object will appear equally bright, and equally distinct, when their linear apertures, and the focal distances of the eye-glasses, are as the square roots of the focal distances of their object-glasses, and consequently their magnifying powers will be as the square roots of the focal distances of the object-glasses.

Upon these principles, we may compute the focal distance of the eye-glasses suited to object-glasses of different focal lengths, provided we have once ascertained by experiment the highest magnifying power that an object-glass of a given focal length will bear with perfect distinctness. One of Huygen's best telescopes, 30 feet long, had an aperture of three inches, with an eye-glass three inches and three-tenths in focal length; and from this telescope, as a standard, the editors of his Dioptrics computed the table given in p. 211 of that work, and reprinted by Dr. Smith in the 148th page of the first

* This excellent astronomer while in England presented the Royal Society with two object-glasses, one of which had a focal length of 120, and the other of 123 feet.

volume of his Optics. It appears, however, from the Astroscopia Compendiari of Huygens, that he possessed a telescope superior even to this, whose object-glass was 34 feet in focal length, and which had a magnifying power of 163 times, with an eye-glass of 2½ inches focal length.

In order to render the common refracting telescope as perfect as possible, without making it achromatic, the spherical aberration should be reduced by grinding the exterior surface of the object-glass to a radius equal to *five-ninths* of its focal length, and the interior surface to a radius equal to *five times* its focal length. In the eye-glasses, the radius of the surface next the object should be *nine* times its focal length, and that of the surface next the eye, three-fifths of the same distance.

When the object to which the telescope is directed is luminous, such as the Sun, and Jupiter, and Venus, when they are near the earth, considerable advantage may be derived from the use of red or green eye-glasses; or, if the telescope is large, from the interposition of plane pieces of green and red glass.

On Meteors, or Falling Stars.

THESE bodies appear to be of different magnitudes, and even of various forms, though this last circumstance may perhaps be the effect of optical deception. In general they seem to be globular, continuing visible only for a few seconds, and moving with great velocity. Their course is on some occasions in a straight line, and on others curvilineal, rendered more distinct by the tail or luminous train which they leave behind them; and before disappearing they are sometimes separated into several smaller bodies, accompanied with an explosion resembling thunder, more or less loud according to their magnitude or distance. It was long supposed, and has now been proved by the most incontrovertible evidence, that these explosions are followed by a shower of solid bodies of a stony or metallic substance, some of which have appeared luminous even in their descent after the explosion, and have been taken up before they had time to cool. This last phenomenon, indeed, is of comparatively rare occurrence. Thousands of small meteors, as various in magnitude and brilliancy as the fixed stars, have been seen in all seasons, and in almost every variety of weather, unaccompanied either with explosions, or the deposition of solid substances; nor is it certain that even the larger and more luminous meteors, such as that of 1783, described by Cavallo, or one in 1811, an account of which was given by Professor Pictet in the *Bibliothèque Britannique* for May, 1811, are always followed by a fall of meteoric stones. On the other hand, these stones have sometimes been observed to fall after a loud detonation, when no meteor was visible, though this may perhaps be accounted for, from its having been obscured either by the superior light of the sun, or the intervention of clouds. But however this

may be, the appearance of large meteors, and the fall of meteoric stones, or, as they have very improperly been called, *aeroliths*, are phenomena that appear to be closely connected, and this is almost all that is known upon the subject. Whether they are all of the same origin, but varying in appearance, in consequence either of their different distances, or of some peculiar state of the atmosphere, or whether they are essentially different in their nature, are questions to which, in the present state of metereological science, no answer can be given. As prognostics of the weather, they have in general been supposed to predict wind, as appears from various passages in ancient authors; and it is also commonly believed, that the wind which follows will blow from the point of the compass towards which the meteor is observed to move. One at least of the various hypotheses which have been proposed to account for these phenomena is interesting, inasmuch as it appears to explain, in certain cases, the connection between the motion of the meteor and the direction of the wind.

The hypothesis to which we allude, is that whi h ascribes meteors to certain vapours arising from the earth, and becoming ignited in the higher regions of the atmosphere. The origin of this opinion may be traced to Aristotle; but from the discoveries in chemistry, of which that author was in a great measure ignorant, it has assumed, in the hands of the modern philosopher, a more definite form. Halley, and after him De Luc, has endeavoured, on this principle, to account for some at least of the circumstances attending the appearance of luminous meteors. The latter supposes that falling stars proceed from a phosphoric fluid, ascending from some spot of the surface of the earth, which becomes visible only when, by decomposition in the higher regions, it takes fire, and light is disengaged. If such a fluid can be supposed to rise in a continued column, without mixing with the atmosphere, or being dispersed by wind, there is no difficulty in conceiving how it may produce the appearance of a falling star. When the upper extremity of the column has reached such a height as to be in a great measure above the region of the clouds and moisture, it may, from the dryness of the air, take fire spontaneously, as phosphorus is known to do when exposed to the atmosphere in its ordinary state; and ignition having once commenced, it may be communicated backward to successive portions of the column, till it arrives at a portion of the atmosphere sufficiently moist to extinguish it, or at the same point where the column itself has been broken and separated. In these circumstances, it is obvious that the appearance would be precisely that of a falling star; and Mr. Forster has ingeniously applied the hypothesis to account for the apparent relation between such phenomena and succeeding gales of wind. It has been long known that different, and even opposite currents of wind, may exist at different heights in the atmosphere at the same time; and the author just referred to, has found, from various experiments and observations, that when the wind near the surface of the earth changes, it frequently blows from the same point from which the current above had previously blown. He observes, therefore, that

De Luc's hypothesis, though he is far from embracing it as satisfactory, will sufficiently account for the relation above stated, by supposing that the column of phosphoric fluid is bent, previous to ignition, in the direction of the upper current; so that, when ignition commences, the luminous body moves towards the point from which that current then proceeds, and from which the lower current is afterwards to blow. It is a prognostication of wind, then, only in so far as it indicates a change that has already commenced in the higher regions of the atmosphere, but which has not yet taken place near the surface of the earth.

On Predicting the Weather.

FROM a very great number of meteorological observations, made in England between the years 1677 and 1789, Mr. Kirwan has deduced the following probable conjectures of the weather:—

1. That when there has been no storm before or after the vernal equinox, the ensuing summer is generally *dry*, at least five times in six.

2. That when a storm happens from any easterly point, either on the 19th, 20th, or 21st of March, the succeeding summer is generally *dry*, four times in five.

3. That when a storm arises on the 25th, 26th, or 27th of March, and not before, in any point, the succeeding summer is generally *dry*, four times in five.

4. If there be a storm at S.W., or W.S.W., on the 19th, 20th, 21st, or 22d of March, the succeeding summer is generally *wet*, four times in five.

To the above we shall add the following observations from the Encyclopedia Britannica.

1. A moist autumn, with a mild winter, is generally followed by a cold and dry spring, which greatly retards vegetation.

2. If the summer be remarkably rainy, it is probable that the ensuing winter will be severe; for the unusual evaporation will have carried off the heat of the earth. Wet summers are generally attended with an unusual quantity of seed on the white thorn and dog-rose bushes. Hence the unusual fruitfulness of these shrubs is a sign of a severe winter.

3. The appearance of cranes, and birds of passage, early in autumn, announces a very severe winter; for it is a sign that it has already begun in the northern countries.

4. When it rains plentifully in May, it will rain but little in September, and vice versa.

5. When the wind is S.W. during summer or autumn, and the temperature of the air unusually cold for the season, both to the feeling and the thermometer, with a low barometer, much rain is to be expected.

6. Violent temperatures, as storms or great rains, produce a sort of crisis in the atmosphere, which produces a constant temperature, good or bad, for some months.

7. A rainy winter predicts a sterile year; a severe autumn announces a windy winter.

On the Construction of the Heavens, by the late Sir W. Herschel.

In a paper on this subject read before the Royal Society, Sir W. Herschel enumerates a great diversity of parts that enter into the construction of the heavens. The first species are insulated stars; as such the author considers our sun, and all the brightest stars, which he supposes nearly out of the reach of mutual gravitation; for, stating the annual parallax of Sirius at 1″, he calculates that Sirius and the sun, if left alone, would be 33 millions of years in falling together; and that the action of the stars of the milky way, as well as others, would tend to protract this time much more. Herschel conjectures that insulated stars alone are surrounded by planets. The next are binary sidereal systems, or double stars; from the great number of these which are visible in different parts of the heavens, and the frequent apparent equality of the two stars, Herschel calculates the very great improbability, that they should be at distances from each other at all comparable to those of the insulated stars: hence he infers, that they must be subjected to mutual gravitation, and can only preserve their relative distances by a periodical revolution round a common centre. In confirmation of this inference, he states that many double stars have actually changed their situation in a progressive course, the motion of some being direct, and of others retrograde. The proper motion of our sun does not appear to be of this kind, but to be rather the effect of some perturbations in the neighbouring systems. The same theory is next applied to triple, quadruple, and multiple systems of stars, and particular hypothetical cases are explained by diagrams. Some such cases, Herschel is fully persuaded, have a real existence in nature. The fourth species consists of clustering stars, and of the milky way; the stars thus disposed constitute masses, which appear brighter in the middle, and fainter towards the extremities, being perhaps collected in a spherical form. Groups of stars the author distinguishes from these by a want of apparent condensation about a centre of attraction: and clusters of stars, by a much more complete compression near such a centre, so as to exhibit a mottled lustre, almost resembling a nucleus. The eighth species consists of nebulæ,

which probably differ from the three last species only in being much more remote; some of them, Herschel calculates, must be at so great a distance, that the rays of light must have been nearly two millions of years in travelling from them to our system. The stellar nebulæ, or stars with burs, form a distinct species. A milky nebulosity is next mentioned, which may in some cases resemble other nebulæ, but in others appear to be diffused, almost like a fluid: the author is not inclined to consider it as either resembling the zodiacal light of the sun, or of a phosphorescent nature. The tenth species is denominated nebulous stars; these are stars surrounded with a nebulosity like an atmosphere, of which the magnitude must be amazingly great; for the apparent diameter of one of them, described in the catalogue, was 3′. The planetary nebulæ are distinguished by their equable brightness, and circular form, while their light is still too faint to be produced by a single luminary of great dimensions. When they have bright central points, Herschel considers them as forming a twelfth species, and supposes them to be allied to the nebulous stars, which might approach to their nature, if their luminous atmospheres were very much condensed round the nucleus.

On the Use of the Telescope.

THE late Sir W. Herschel has remarked, that, "In order to see well with telescopes, it is required that the temperature of the atmosphere and mirror should be uniform, and the air fraught with moisture." Thus a frost after a thaw, or a thaw after a frost, will impair the perfection of the focus: a telescope brought out of a warm room into a cold air, or even directed through an aperture of any kind, acts but imperfectly: windy weather is unfavourable to distinct vision, from a mixture of air of different temperatures: an aurora borealis sometimes affects the distinctness of the view, as well as the air ascending from the warm roof of a house: dampness fogs, and the neighbourhood of moisture, are very favourable to distinct vision with telescopes, except when a fog is so opaque as totally to intercept it. Sir W^r. Herschel remarks, that some of these obstacles are insuperable; but that the effect of heat may sometimes be remedied by the application of a heated body near the opposite surface of the mirror.

Sir W. also observes, that the central part of a mirror produces a greater aberration in the image of a fixed star than the whole mirror, and the whole mirror a greater aberration than an annular portion remote from the centre: and that this is true of all good mirrors.*

* Some additional and useful remarks on the nature and application of the telescope, by the same author, will be found at page 81 of this work.

TABLE I.

Right Ascensions and Declinations of the Principal Fixed Stars, adapted to the *Beginning* of the Year 1824.

Names of the Stars.		Mag.	Right Ascension in Time. H. M. S.	Ann. Var. add. s.	Declination. ° ′ ″	Ann. Var. ″
γ Pegasus	*Algenib*	2	0 4 11	3·1	14 12 20 N.	+ 20
α Phœnix		2·3	0 17 34	3·0	43 15 10 S.	— 20
β Cetus		2·3	0 34 44	3·0	18 57 16 S.	— 20
β Andromeda ..	*Mirach*	2	0 59 53	3·3	34 41 9 N.	+ 19
α Eridanus	*Achernar*	1	1 31 8	2·2	58 7 58 S.	— 19
α Aries	Arietis	2	1 57 16	3·4	22 37 34 N.	+ 17
γ Cetus		3	2 34 11	3·1	2 29 38 N.	+ 16
α Cetus	*Menkar*	2	2 53 5	3·1	3 23 41 N.	+ 15
β Perseus	*Algol*	Var.	2 56 46	3·8	40 16 15 N.	+ 14
α Perseus		2	3 11 48	4·2	49 13 36 N.	+ 14
α Taurus ..	Aldebaran	1	4 25 50	3·4	16 8 54 N.	+ 8
α Auriga	*Capella*	1	5 3 42	4·4	45 48 29 N.	+ 5
β Orion	*Rigel*	1	5 6 5	2·9	8 24 40 N.	— 5
β Taurus		2	5 15 11	3·8	28 26 59 N.	+ 4
γ Orion	*Bellatrix*	2	5 15 42	3·2	6 10 59 N.	+ 4
α Columba		2	5 33 18	2·2	34 10 20 S.	— 2
η Orion		2·3	5 39 25	2·8	9 44 15 S.	— 2
α Orion	*Betelguese*	1	5 35 39	3·4	7 21 59 N.	+ 1
α Argo Navis	*Canopus*	1	6 20 3	1·3	52 36 9 S.	+ 2
α Canis Major ..	*Sirius*	1	6 37 24	2·6	16 28 48 S.	+ 4
δ Canis Major		2·3	7 1 15	2·4	26 7 14 S.	+ 5
η Canis Major		2·3	7 17 8	2·4	28 57 52 S.	+ 7
α Gemini	*Castor*	1	7 23 22	3·8	32 15 56 N.	— 7
α Canis Minor ..	*Procyon*	1·2	7 30 5	3·2	5 40 11 N.	— 9
β Gemini	Pollux	1	7 34 32	3·7	28 26 36 N.	— 8
ζ Argo Navis		2	7 57 24	2·1	39 30 38 S.	+ 10
γ Argo Navis		2	8 4 8	1·8	46 49 11 S.	+ 10
δ Argo Navis		2	8 39 52	1·6	54 3 45 S.	+ 13
β Argo Navis		1	9 11 17	0·7	68 39 42 S.	+ 15
α Hydra	*Alphard*	2	9 18 56	3·0	7 53 58 S.	+ 15
α Leo	Regulus	1	9 58 59	3·2	12 49 27 N.	— 17
β Ursa Major		2	10 51 10	3·7	57 19 25 N.	— 19
α Ursa Major ..	*Dubhe*	1·2	10 52 47	3·8	62 41 57 N.	— 19
β Leo	*Deneb*	2	11 40 5	3·1	15 33 22 N.	— 20
α Crux		1	12 16 54	3·2	62 7 29 S.	+ 20
γ Crux		2	12 21 26	3·3	56 7 21 S.	+ 20
β Crux		2	12 37 30	3·4	58 43 33 S.	+ 20
α Virgo	Spica	1	13 15 56	3·1	10 14 19 S.	+ 19
η Ursa Major ..	*Benetnach*	2	13 40 36	2·4	50 11 42 N.	— 18
β Centaurus		2	13 51 30	4·1	59 31 2 S.	+ 18
α Draco		2·3	13 59 39	1·6	65 13 8 N.	— 17
α Bootes	*Arcturus*	1	14 7 39	2·7	20 6 12 N.	— 19
α Centaurus		1	14 28 18	4·4	60 7 5 S.	+ 16
α Libra	*Zubenesch*	2·3	14 41 4	3·3	15 16 48 S.	+ 15
β Libra	*Zubenelg*	2·3	15 7 34	3·2	8 43 38 S.	+ 14
α Corona Borealis ..	*Alphacca*	2	15 27 15	2·5	27 18 47 N.	— 12
α Serpens		2	15 35 36	2·9	6 59 11 N.	— 12
α Scorpio	Antares	1	16 18 37	3·6	26 1 50 S.	+ 9
α Hercules ..	*Ras Algethi*	2	17 6 38	2·7	14 35 56 N.	— 4
α Serpentarius ..	*Ras Alhague*	2	17 26 46	2·8	12 41 47 N.	— 3
γ Draco	*Rastaban*	2·3	17 52 31	1·4	51 30 48 N.	— 1
α Lyra	*Vega*	1	18 30 59	2·0	38 37 33 N.	+ 3
α Aquila	Altair	1·2	19 42 12	2·9	8 24 41 N.	+ 9
α Pavo		1·2	20 11 40	4·8	57 17 19 S.	— 11
α Cygnus	*Arided*	1·2	20 35 26	2·0	44 39 21 N.	+ 13
α Cepheus ..	*Alderaimin*	3	21 14 23	1·4	61 50 31 N.	+ 15
α Grus		2	21 57 6	3·8	47 48 11 S.	— 17
α Pisces Aust.	Fomalhaut	1	22 47 54	3·3	30 33 10 S.	— 19
β Pegasus	*Scheat*	2	22 55 15	2·9	27 7 37 N.	+ 19
α Pegasus	Marcab	2	22 56 0	3·0	14 16 42 N.	+ 19
α Andromeda ..	*Alpheratz*	2	23 59 19	3·1	28 17 10 N.	+ 20

Remarks on different Hypotheses respecting the Moon, and various Phenomena of that Planet.

We make no apology for submitting to our readers the subjoined extracts from a highly ingenious and interesting work, entitled Selenognostic Fragments, published by Dr. Gruithuisen, whose name ranks deservedly high in the list of foreign astronomers.

No body in the starry heavens, observes the Doctor, in his introduction, excites more general interest than the faithful satellite of the earth: in fact, its surface presents, even to the naked eye, objects so varied, that it instantly inspires the spectator with a wish to inspect this unknown world, with the aid of a powerful telescope. But what especially prompts us to study the physical properties and constitution of the moon, is the expectation of discovering an analogy common to all the great bodies of the universe, with respect to their organization. This, he adds, is what has hitherto been the foundation of my celestial observations, being myself convinced that we shall never attain to any excellence in the study of geognosy, till we have discovered this analogy. It is with this intention that the author has surveyed, examined, and studied many chains of terrestrial mountains; and it is with this view that he publishes the particular appearances, which eight years observations have enabled him to remark upon the surface of the moon.

To render his work more intelligible to his readers, the Doctor has inserted a lithographic general map of this planet; for which purpose he has consulted Mayer's draught of the moon, and the special maps given by Schrœter in his Selenographic Fragments. Nor has he neglected to avail himself of his own observations. He likewise cites the lunar map of Lambert, and refers to a memoir of that philosopher in the first volume of the Berlin astronomical almanack.

Atmosphere of the Moon. Cassini, Louville, Bianchini, Carbone, Euler, Krüger, Boscovich, Ulloa, Dusejour, Wolf, and Halle, maintain the existence of a lunar atmosphere; while Mayer, Grandjean de Fouchy, De l'Isle, and De la Hire, deny it. Without dwelling upon the reasons and observations which, before the invention of achromatic telescopes have been alleged on both sides of the questions, Doctor Gruithuisen confines himself to the direct proofs drawn from the discoveries of Schrœter. The latter has calculated the elevation of the twilight observed by him in repeated observations on the increasing moon. This elevation agrees in a surprising manner with the theorem of Melanderhielm; namely, that on the surface of planets the density of their atmospheres is in proportion to the squares of the weight of the bodies. This proportion had been suggested to Newton by that of the squares of weights on the surface of the moon, and the surface of the earth. In fact, this latter proportion being as 1 to 28·40, is almost equal to the result of Schrœter, who found that the lunar atmosphere is 28·94 times less dense than our own. Hevelius, Deluc, and many other philosophers, have thought that the air on the surface of planets was only ether condensed, and have considered ether, in its turn, as rarified air, an

opinion, which, in a theoretical point of view, confirms the theorem of Melanderhielm.

To attempt to combat this theory, adds our author, would have the effect of entangling us in a multitude of inextricable difficulties: for we must then affirm that ether and air have no communication together; that consequently they cannot mix, and that there is between them a kind of barrier, as if our earth was enclosed in a globe of hollow glass: yet we know that all gases mingle together, which, moreover, must happen from the pressure of our air upon ether, and, reciprocally, on account of the rapid motion of the earth. It is to this pressure that M. de Zach attributes the diurnal oscillations of the barometer, observed at the equator by Humboldt. We should likewise be obliged to affirm, that as the air of planets is essentially different from ether, there can be no affinity between them, and consequently that nobody can burn in ether for want of oxygen, a conclusion not warranted by observations, since shooting stars and meteors burn and shine at a height at which in general the presence of atmospheric air is not supposed. For example, in 1795, Schrœter saw, with his reflecting telescope of 20 feet long, a shooting star, the height of which he estimated at more than four millions of miles. If then it be admitted that each body of the universe, by the influence of a weight proportioned to its bulk, forms out of ether, the atmosphere by which it is surrounded, then the moon must also borrow from ether its portion, which becomes condensed and forms its atmosphere. The existence of water in the lunar atmosphere can no longer be questioned, for clouds have been seen upon its surface, as is proved by the almost innumerable observations of Schrœter, to whose work the Doctor refers for more extensive details.

Organised Beings in the Moon. It is a remarkable circumstance, observes M. Gruithuisen, that all those who only take what may be termed a cursory survey of the moon through a telescope, consider it as a desert and globe, upon which nothing lives or grows: on the contrary, others who have explored its surface for many years, speak of it, as if organised beings could not fail to exist there.

Shrœter conjectures the existence of a town towards the north of *murius* (a lunar spot), and the canals which are observable towards *hyginus* (another spot), and which, after disappearing in some places, are again perceived in others (a thing, says Dr. G. of which I have convinced myself), appear to him very advantageous for the commerce of the *Selenites:* finally, he represents a part of the spot named *mare imbrium* to be as fertile as Campania.

The ancients supposed the moon to be inhabited. Orpheus, Anaxagoras, Xenophon, and Pythagoras, are of this opinion. Their strength of reasoning compensated, in this instance, for their want of telescopes: even Plutarch entertained the idea, that the obscure places on the moon's surface were seas, which could not reflect the light of the sun. More recently, Kepler, Duhamel, and many others have been of the same way of thinking respecting the existence of the *Selenites.* Indeed, so general has this sentiment been, that even the American savages have believed the moon to be inhabited.

In latter times, some persons have considered the too great rarefaction of the air as an insuperable obstacle to peopling the moon. Without doubt, says our author, this circumstance would not fail to alarm more than one philosopher of a delicate constitution, particularly when he knows that neither raisins nor apricots are to be found even on the Chimboraço. Others, on the contrary, have not forgotten that Mr. Guy-Lussac ascended, with his balloon, to a height greater by 2000 feet than the height of that mountain. So that an inhabitant of our globe, if placed in the lowest regions of the moon, might find himself very ill at his ease, but not so much so as to cause his death.

While speaking of the inhabitants of the moon, we may observe, that some theorists have affirmed that no animated beings could exist on that planet, but such as were capable of eating stones, doing without drink, living on a scanty supply of air, and supporting the extremes of heat and cold. These particulars, adds Mr. Guithuisen, may be considered as a summing up of all the doubts that have arisen on the question whether the planets are habitable or not. He then discusses each of these points. He thinks he can confidently affirm that the moon has vegetables and animals to serve for food to its inhabitants: he even goes so far as to indicate some of their genera and species. In the absence of wine, he continues, the *Selenites* have water, so that they possess the means of quenching their thirst. They are likewise supplied with air in more than sufficient quantity, only that this air is extremely rarefied. If we admit of lakes and seas in the moon, why should they not contain shell and other fish, and amphibious beings? And that man can accustom himself to a highly rarefied atmosphere, has been shewn by the aerial ascent of M. Guy-Lussac, already referred to. According to Humboldt, the atmosphere supports a column of quicksilver of only twenty inches at Quito; of eighteen inches at Micuipampa, and of seventeen inches in the latitude of Antisana, all inhabited places upon the earth, notwithstanding this rarefaction. Lastly, the *Selenites* can face the cold and heat with the assistance of fire, which they have the means of procuring in the former case; and in the latter, by means of the deep caverns, in whose coolness they can obtain refuge from the heat.

Waters in the Moon. By these, says our author, I understand all the springs, rivers, lakes, and seas. After having collected and discussed at great length all the facts calculated to illustrate the subject, he thinks he has a right to ask, who can now bring forward any probable argument against the existence of lakes in the moon! But, he adds, lakes presuppose rivers, or at least simple rivulets or springs, their existence is then sufficiently demonstrated.

Of the Lunar Structure. The interior structure of the moon is probably not different from that which is common to all the bodies of the universe; namely, concentric beds formed by the accumulation of successive strata.

Of the Exterior Structure or Constitution. This consists properly in

the chains of mountains; the caverns, the declivities and the acclivities are immediate consequences of this disposition.

We shall only add a few words relative to the lithographical map which Doctor Gruithuisen has attached to his work, for the purpose of facilitating the discovery of the points, which he more particularly wishes to designate upon the face of the moon. To accomplish this, he indicates their situation by their distance from two lines, which may be said to represent the equator and the first meridian of the moon, which we consider to be a felicitous and useful imitation of terrestrial longitudes and latitudes.

On Professor Struve's Observations to determine the Parallax of the fixed Stars

Of the various attempts to discover the parallax of the fixed stars, the observations of Professor Struve must be regarded as among the best, and most judicious.

His object is, by means of an excellent transit instrument furnished with seven wires, to determine the sum of the parallaxes of several fixed stars, differing nearly 12 hours in right ascension from each other

The results which he obtains, seem to verify a remark made by Mr. Pond, that in proportion as any improvement takes place either in our instruments or our processes, the resulting parallax becomes proportionally less.

Of fourteen sets of opposite stars thus compared, Mr. Struve finds seven, which give the parallax *negative;* this circumstance alone should suggest great caution in attributing to the effects of parallax the small positive quantities that are derived from the remaining seven. Mr Struve however is inclined to assign 0".16 of space as the parallax of δ Ursæ Minoris, and 0".45 for the sum of the parallaxes of α Cigni, and ι Ursæ Majoris. His learned coadjutor, M. Walbeck, who, it appears, has undertaken the calculations, is disposed to attribute the greatest portion of this parallax to the smaller star; a circumstance so improbable requires very strong evidence for its support.

If we take the mean of the fourteen results as relating generally to stars from the 1st to the 4th magnitude, it will appear that the mean sum of the parallaxes of two opposite stars is equal to 0" 036 of space, or the parallax of a single star equal to 0".018.

If any reliance can be placed on these observations, every attempt to determine the parallax of these stars in declination must be entirely hopeless; since in this case we can only measure the shorter axis of the Ellipse, and the uncertainty of refraction must amount, at least, to twenty times the quantity we are in search of.

On the Method of Determining the Figure of the Earth by the Pendulum.

THE method of determining the figure of the earth by means of the *pendulum*, depends upon the variation of gravity at the earth's surface. This subtile and pervading power, tends to communicate to bodies exposed to its influence equal velocities in equal times. One of the modifications of this action is the oscillation of the pendulum, which is of longer or shorter duration, according to the energy of the attractive force, and the square root of the length of the pendulum. If the earth were an exact sphere, destitute of the motion of rotation, and possessing the same density throughout its whole mass, the force of gravity, by which bodies at its surface are drawn towards the centre, would be uniform, and invariable in every latitude. But the elliptical form of the earth destroys this uniformity, and causes the attractive force at the poles to preponderate over that at the equator. This inequality in the force, by which bodies at the surface of the earth retain their positions, is augmented by the diurnal rotation, which, by centrifugal tendency, impresses a greater disposition on bodies to recede from the centre of the earth at the equator than at the poles, where its effects cease to be felt. By the joint operation of these two causes, one of which acts with a force proportional to the square of the sine of the latitude, a sensible difference ought to be observed in the velocity acquired by heavy bodies, in falling through the same space, as we advance from the equator to the poles. An important relation between the time of the vibration of a pendulum, and that o the descent of a heavy body, according to which the lengths of pendulums, vibrating ischronously, are directly as the force of gravity, enables us to submit this conclusion to the test of experiment. Newton long ago demonstrated, that if the earth were perfectly homogeneous, the same fraction, viz. $\frac{1}{230}$, would express both the compression of the terrestrial ellipsoid, and the increase of gravity from the equator to the poles. This conclusion, which was deduced from the supposition of an uniform density, was afterwards modified, with singular address, by Clairaut, who showed, that the two fractions expressing the compression, and the increase of grvity, though not exactly equal, must always together amount to $\frac{2}{230}$. Assuming the compression, therefore, to be equal to $\frac{1}{312}$, the increase of gravity from the equator to the poles, or the indication of that increase, as given by the length of the pendulum, should be $\frac{2}{230}-\frac{1}{312}$, or $\frac{1}{182}$ nearly. The correctness of this conclusion, if not completely established, is, at least, to a certain extent, confirmed, by the experiments which have been made with the pendulum in different latitudes. La Place having selected fifteen of the best of these observations, and applied to them the necessary corrections, on account of the resistance of the air, difference of temperature, and elevation above the level of the sea, deduced the following results, in which the length of the pendulum at Paris is considered to be unity.

Latitude.	Length of the Seconds Pendulum.	Names of the Observers.	Places of Observation.
Equator	·99669	Bouguer	Peru
9 32 56′	·99689	Ditto	Portobello
11 55 30	·99710	Gentil	Pondicherry
18 0 0	·99745	Campbell	Jamaica
18 27 0	·99728	Bouguer	Petit Grave
34 7 15	·99877	La Caille	Cape G. H.
43 35 45	·99950	Darquier	Toulouse
48 12 48	·99077	Liesganig	Vienna
48 50 0	1·00000	Bouguer	Paris
50 58 0	1·00006	Zach	Gotha
51 30 0	1·00018		London
58 14 53	1·00074	Mallet	Petersburgh
59 56 21	1·00101	Ditto	Ponoi
66 48 0	1·00137	Grischow	Arensberg
67 5 0	1·00148	Mapertius	Tornea

The above results indicate obviously an increase of the force of gravity from the equator towards the poles. La Place has shewn that, in whatever way they are combined, it is impossible to avoid an error of less than ·00018, on the hypothesis of the variation of gravity at the surface of the earth increasing as the squares of the sines of the latitude from the equator to the poles. The expression for the ellipticity, which connects best the different equations of condition, is $\frac{1}{335 \cdot 78}$, a result which accords in a very remarkable manner with the compression deduced from the measures of the French mathematicians in France, and at the equator.

It may be inferred from these experiments with the pendulum, that the compression of the earth is greater than is compatible with the supposition of an uniform density. The same anomalies, too, which are discernible in the measurement of a degree of the meridian, and which are undoubtedly owing to the dissimilar structure of the globe, may be traced in the results of these experiments. The beautiful property of the pendulum, first discovered by Huggens, that the centre of oscillation and the point of suspension, are interchangeable with each other, and which has been so happily applied by Captain Kater, to determine the length of the seconds' pendulum, renders this mechanical contrivance infinitely better fitted to ascertain the true figure of the earth, than the complicated methods which were formerly employed for the same purpose. The facility with which the observations may be made, and the certainty of the results with which they are attended, may be expected to furnish much interesting information, not only with respect to the general form of the globe, but also with respect to its structure and composition in particular situations.

TABLE.

Time to be added to the Right Ascension of a Star, to find the Time of its Passing the Meridian on any day of the Year

Day	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Day
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	
1	5 14	3 [illegible]	1 1	23 18	21 27	19 25	17 20	15 15	13 19	11 31	9 35	7 31	1
2	5 10	2 58	1 8	23 15	21 23	19 20	17 16	15 11	13 16	11 28	9 31	7 27	2
3	5 6	2 54	1 4	23 11	21 20	19 16	17 12	15 8	13 12	11 24	9 27	7 23	3
4	5 1	2 50	1 1	23 7	21 16	19 1	17 8	15 4	13 8	11 20	9 23	7 18	4
5	4 57	2 46	0 57	23 4	21 12	19 8	17 4	15 0	13 5	11 17	9 19	7 14	5
6	4 52	2 42	0 53	23 0	21 8	19 4	17 0	14 56	13 1	11 13	9 15	7 9	6
7	4 48	2 38	0 50	22 56	21 4	19 0	16 56	14 52	12 58	11 9	9 11	7 5	7
8	4 44	2 34	0 46	22 53	21 0	18 56	16 51	14 48	12 54	11 6	9 7	7 1	8
9	4 39	2 30	0 42	22 49	20 56	18 52	16 47	14 45	12 50	11 2	9 3	6 56	9
10	4 35	2 26	0 39	22 45	20 52	18 47	16 43	14 41	12 47	10 58	8 59	6 52	10
11	4 31	2 22	0 35	22 42	20 49	18 43	16 39	14 37	12 43	10 55	8 55	6 47	11
12	4 26	2 18	0 31	22 38	20 45	18 39	16 35	14 33	12 40	10 51	8 51	6 43	12
13	4 [illegible]	2 14	0 27	22 34	20 41	18 35	16 31	14 29	12 36	10 47	8 47	6 39	13
14	4 18	2 10	0 24	22 31	20 37	18 31	16 27	14 26	12 32	10 44	8 43	6 34	14
15	4 13	2 6	0 20	22 27	20 33	18 27	16 23	14 22	12 29	10 40	8 39	6 30	15
16	4 9	2 2	0 17	22 23	20 29	18 23	16 19	14 18	12 25	10 36	8 35	6 25	16
17	4 5	1 58	0 13	22 20	20 25	18 18	16 15	14 14	12 22	10 32	8 30	6 21	17
18	4 0	1 55	0 9	22 16	20 21	18 14	16 11	14 11	12 18	10 29	8 26	6 17	18
19	3 56	1 51	0 6	22 12	20 17	18 10	16 7	14 7	12 14	10 25	8 22	6 12	19
20	3 52	1 47	0 2	22 9	20 13	18 6	16 3	14 3	12 11	10 21	8 18	6 8	20
21	3 48	1 43	23 58	22 5	20 9	18 2	15 59	14 0	12 7	10 17	8 14	6 3	21
22	3 43	1 39	23 55	22 1	20 5	17 58	15 55	13 56	12 4	10 14	8 10	5 59	22
23	3 39	1 35	23 51	21 57	20 1	17 53	15 51	13 52	12 0	10 10	8 5	5 54	23
24	3 35	1 32	23 47	21 54	19 57	17 49	15 47	13 48	11 56	10 6	8 1	5 50	24
25	3 31	1 28	23 44	21 50	19 53	17 45	15 43	13 45	11 53	10 2	7 57	5 45	25
26	3 27	1 24	23 40	21 46	19 49	17 41	15 39	13 41	11 49	9 58	7 53	5 41	26
27	3 23	1 20	23 37	21 42	19 45	17 37	15 35	13 37	11 46	9 54	7 48	5 [illegible]	27
28	3 18	1 17	23 33	21 39	19 41	17 33	15 31	13 34	11 42	9 51	7 44	5 [illegible]	28
29	3 14	1 14	23 29	21 35	19 37	17 29	15 27	13 30	11 38	9 47	7 40	5 28	29
30	3 10		23 26	21 31	19 33	17 21	15 23	13 27	11 35	9 43	7 35	5 23	30
31	3 6		23 22		19 29		15 19	13 23		9 39		5 19	31

Water Spouts.

Remarkable Water-spout in France in 1823.—In the arrondissemens of Dreux and of Mantes, about 3 o'clock of the 26th of August, 1823, a storm came on from the S.W., accompanied with a sudden and powerful heat. A water-spout was seen not far from the village of Boncourt, having its broad base resting on the ground, and its summit lost in the clouds. It consisted of a thick and blackish vapour, in the *middle of which were often seen flames in several directions.* Advancing along with the storm, it broke or tore up by the roots, in the space of a league, seven or eight hundred trees of different sizes, and at last burst with great violence in the village of Marchepoy, one half of the houses of which were instantly destroyed. The walls, overturned to their foundations, rolled down on all sides; the roofs, when carried off, broke in pieces, and the debris were dragged to the distance of half a league by the force of this aërial torrent. Some of the inhabitants were crushed to pieces, or wounded by the fall of their houses, and those who were occupied in the labours of the field, were overthrown or blown away by the whirlwind. Hailstones as large as the fist, and stones and other foreign bodies carried off by the wind, injured several individuals. Carts heavily loaded were broken in pieces, and their loads dispersed. Their axle-trees were broken, and the wheels were found at the distance of 200 or 300 paces from the spot where they were overturned. One of these carts, which had been carried off almost bodily, was pitched above a tile-kiln, which had been beaten down, and some of the materials of which had been carried to a considerable distance. A spire, several hamlets, and different insulated houses, were overthrown. Several villages were considerably injured. The lower part of the water-spout is supposed to have been about 100 toises in diameter.—See the *Moniteur* of the 31st October, where the account is signed by M. Foucault, and the *Bibl. Univers.* Oct. 1823, p. 133.

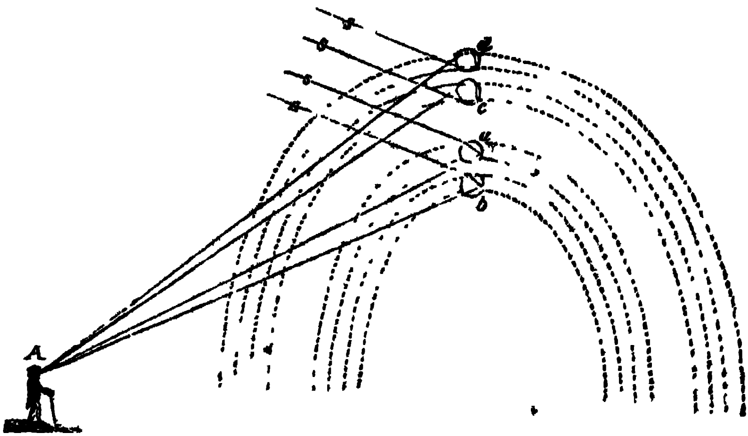
Water-spout near Genoa in 1823.—In the communes of Quigliano and Valeggia, in the province of Savona, a heavy rain fell on the 16th September, at 5 o'clock in the morning. It increased to such a degree, that at 9 o'clock in the morning the country was inundated. Towards noon there issued from a mountain situated in the parish of Valeggia, a whirlwind of black smoke and fire. It first carried off the roof of a house, in which two children were crushed to pieces, and the parents wounded. The water-spout then advanced to the opposite side of the mountain, called Magliolo; crossed the river, the waters of which it heaped up in an instant, though they were much swelled;—carried off the roofs of two inhabited houses, and advanced along the same mountain in the district of Quigliano, where it dissipated itself near the Convent of Capuchins, situated in the village. It tore up many large trees of all kinds, and committed ravages, the extent of which is not yet known. The preceding account was sent by the commandant of the province of Savona to the governor of Genoa, in a letter, part of which is published in the *Moniteur* of the 1st of October, and in the *Bibl. Univers.* Nov. 1823, p. 135.

Of the Rainbow.

THE phenomena of the rainbow consists, as every person knows, of two bows, or arches, stretching across the sky, and tinged with all the colours of the prismatic spectrum. The internal or principal rainbow, which is often seen without the other, has the *violet* rays *innermost*, and the *red* rays *outermost*. The external, or secondary rainbow, which is much fainter than the other, has the violet colour outermost, and the red colour innermost. Sometimes supernumerary bows are seen to accompany the principal bows.

As the rainbow is never seen unless when the sun shines, and when rain is falling, it has been universally ascribed to the decomposition of white light by the refraction of the drops of rain, and their reflection within the drops. The production of rainbows by the spray of water-falls, or by drops of water scattered by a brush or syringe, is an experimental proof of their origin.

Let an observer be placed with his back to the sun, and his eye directed through a shower of rain to the part of the sky opposite to the sun. As the drops of rain are spherical particles of water, they will reflect and refract the sun's rays, according to the usual laws of refraction and reflection. Thus, in the following figure, where *s s s s* represent the sun's rays, and A the place of a spectator, in the centre of the two bows (the planes of which are supposed to be perpendicular to his view), the drops *a* and *b* produce part of the *inner* bow by two refractions and one reflection;



and the drops *c* and *d* part of the exterior bow, by two refractions and one reflection.

This holds good at whatever height the sun may chance to be in a shower of rain; if high, the rainbow must be low; if the sun be low, the rainbow is high: and if a shower happen in a vale when a spectator is on a mountain, he often sees the bow completed to a circle below him. So, in the spray of the sea, or a cascade, a circular rain-

bow is often seen; and it is but the interposition of the earth that prevents a circular spectrum from being seen at all times, the eye being the vertex of a cone, whose base (the bow) is in part cut off by the earth.

It is only necessary, for the formation of a rainbow, that the sun should shine on a dense cloud, or a shower of rain, in a proper situation, or even on a number of minute drops of water, scattered by a brush or by a syringe, so that the the light may reach the eye after having undergone a certain angular deviation, by means of various refractions and reflections, as already stated. The light which is reflected by the external surface of a sphere, is scattered almost equally in all directions, setting aside the difference arising from the greater efficacy of oblique reflection: but when it first enters the drop, and is there reflected by its posterior surface, its deviation never exceeds a certain angle, which depends on, the degree of refrangibility, and is, therefore, different for light of different colours: and the density of the light being the greatest at the angle of greatest deviation, the appearance of a luminous arch is produced by the rays of each colour at its appropriate distance. The rays which never enter the drops produce no other effect, than to cause a brightness, or haziness, round the sun, where the reflection is the most oblique: those which are once reflected within the drop, exhibit the common internal or primary rainbow, at the distance of about 41 degrees from the point opposite to the sun: those which are twice reflected, the external or secondary rainbow, of 52 degrees; and if the effect of the light, three times reflected, were sufficiently powerful, it would appear at the distance of about 42 degrees from the sun. The colours of both rainbows encroach considerably on each other; for each point of the sun may be considered as affording a distinct arch of each colour, and the whole disc, as producing an arch about half a degree in breadth, for each kind of light; so that the arrangement nearly resembles that of the common mixed spectrum.

A *lunar rainbow* is much more rarely seen than a solar one; but its colours differ little, except in intensity, from those of the common rainbow.

The appearance of a rainbow may be produced at any time, when the sun shines, as follows; opposite to a window, into which the sun shines, suspend a glass globe, filled with clear water, in such a manner as to be able to raise it or lower it at pleasure, in order that the sun's rays may strike upon it. Raise the globe gradually, and when it gets to the altitude of forty degrees, a person standing in a proper situation, will perceive a purple colour in the glass, and upon raising it higher the other prismatic colours, blue, green, yellow, orange, and red, will successively appear. After this, the colours will disappear, till the globe be raised to about fifty degrees, when they will again be seen, but in an inverted order; the red appearing first, and the blue, or violet, last. Upon raising the globe to about fifty-four degrees, the colours will totally vanish.

In the highest northern latitudes, where the air is commonly loaded with frozen particles, the sun and moon usually appear surrounded by *halos*, or coloured circles, at the distances of about 22

and 46 degrees from their centres. Several new forms of *halos* and *paraselenae*, or mock-moons, have been described by Captain Ross and Captain Parry. And Captain Scoresby, in his account of the Arctic Regions, has delineated an immense number of particles of snow, which assume the most beautiful and varied crystallizations, all depending more or less on six-sided combinations of minute particles of ice.

When particles of such forms are floating or descending in the air, there can be no difficulty in deriving from them those various and intricate forms which are occasionally met with among this class of phenomena.

Halos are frequently observed in other climates, as well as in the northern regions of the globe, especially in the colder months, and in the light clouds which float in the highest regions of the air. The halos are usually attended by a horizontal white circle, with brighter spots, or parhelia, near their intersections with this circle, and with portions of inverted arches of various curvatures; the horizontal circle has also sometimes *anthelia*, or bright spots nearly opposite to the sun. These phenomena have usually been attributed to the effect of spherical particles of hail, each having a central opaque portion of a certain magnitude, mixed with oblong particles, of a determinate form, and floating with a certain constant obliquity to the horizon. But all these arbitrary suppositions, which were imagined by Huygens, are in themselves extremely complicated and improbable. A much simpler, and more natural, as well as more accurate explanation, which was suggested at an earlier period by Mariotte, had long been wholly forgotten, till the same idea occurred to Dr. Young. The explanation given by the last mentioned philosophers is, that water has a tendency to congeal or crystallize in the form of a prism, and that the rays of light passing through these prisms (which are disposed in various positions,) by their own weight, are so refracted as to produce the different appearances which halos and parhelia have been observed to assume.

The colours which these phenomena exhibit, are nearly the same as the rainbow, but less distinct; the red being nearest to the luminary, and the whole halo being very ill defined on the exterior side. Sometimes the figures of halos and parhelia are so complicated, as to defy all attempts to account for the formation of their different parts; but if the various forms and appearances which the flakes of snow assume, be considered, there will be no reason to think them inadequate to the production of *all* these appearances.

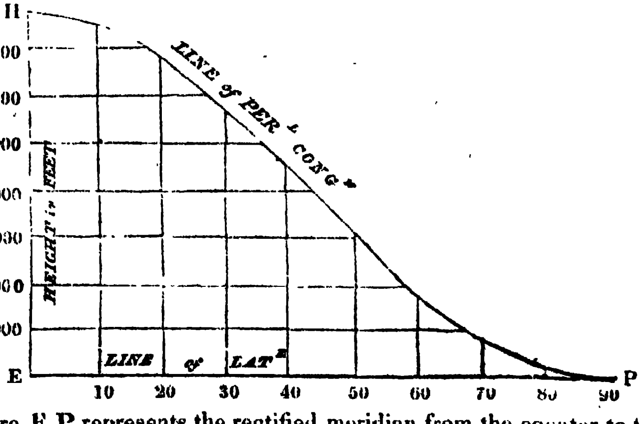
On the Line of Perpetual Congelation.

In consequence of the diminution of temperature which is experienced as we ascend in the atmosphere, it is evident that in every climate a point of elevation may be reached where it will be continually freezing. The altitude of the point above the surface of the earth, will depend partly on the temperature of the lower regions of the atmosphere, and partly on the decrement of heat belonging to the column at the period of observation. Thus, near the equator, it was observed by Bouguer, that it began to freeze on the sides of

the lofty mountain Pinchencha, at the height of 15,577 feet above the level of the sea, whereas congelation was found by Saussure to take place on the Alps at the height of 13,428 feet. By tracing a line on the plane of the meridian, through the points at which it constantly freezes, a curve is obtained, which has been denominated the line of *Perpetual Congelation.* The height at which this curve intersects a vertical line in the various latitudes, has been computed by Kirwan, partly from observation, and partly from the mean temperature of the parallel, and the decrement of heat, as we ascend in the atmosphere. The following table exhibits the result of his calculations; and though it is constructed on the erroneous supposition, that the mean annual temperature of the pole is 31°, which, according to the observations of Captain Scoresby and Captain Parry, must be far beyond the truth, it is tolerably accurate for the more accessible regions of the globe.

Latitude.	*Mean Height of Line of Congelation.*	*Latitude.*	*Mean Height of Line of Congelation.*
0	15,577	45	7,658
5	15,157	50	6,260
10	15,067	55	4,912
15	15,498	60	3,684
20	13,719	65	2,516
25	13,030	70	1,557
30	11,592	75	748
35	10,664	80	128
40	9,016		

These numerical relations will be best perceived at a glance, by means of the following diagram:—



Here E P represents the rectified meridian from the equator to the pole, divided into intervals of 10° each; and the different perpendiculars or ordinates at the point 0, 10, 20, &c. represent the height of the *freezing point* at the equator, and at latitude 10, 20, &c. to the pole P. The curve H P, which has a contrary flexure about 60°, exhibits the general form of the line of Perpetual Congelation from the equator to the pole.

On the manner of Regulating Public Clocks. *By* J. Littrow, *Director of the Observatory of Vienna.*

Up to this time, says the Author, in our town and many others, persons have been appointed for the express purpose of regulating the public clocks: every one knows by experience in what manner they discharge this duty.

The first thing to be desired is that public clocks should agree better, if not with the heavens, at least with one another, to obviate the possibility of mistakes arising in keeping appointments at any given time. Undoubtedly it is sufficient for many persons if the town clocks keep time tolerably together, whether right or wrong; but there are likewise many others to whom it is of importance that they should go correctly. In fact, if the principal church clock, by which the others must be regulated, be bad (and the best clocks of this description are so, if compared with astronomical clocks), it will go sometimes too slow, sometimes too fast, and it will be necessary sometimes to put the other clocks back, and sometimes forward, although they are often better than the principal ones. It will be the same with regard to private clocks, which, adds Mr. Littrow, must be continually adjusted, to make them agree with the principal town-clock, by which all the others must be regulated.

Thus the public clocks, if we wish to establish systematic order, ought not only to agree together, but the clock which serves to regulate the others must go well, and correspond exactly to the great celestial clock; this must be the second necessary condition. But how is this conformity to be brought about? The pretended regulating clocks, or the common pendulums frequently used for that purpose, are of no great utility, on account of their elevated situation, of their being exposed to the influence of variations of temperature, and to the high winds which cannot fail to agitate lofty towers, and of the oscillatory movement communicated by the bells, at the time of striking, to the whole building. The solar dials of themselves are too small and too imperfect, to expect from them the exactness necessary in such a case. Meridians, besides various other inconveniences, are of no use except when the sun appears precisely at noon. If, which is not uncommon in our foggy months of winter, the sun is three or four weeks concealed behind the clouds, at noon-time, even when the rest of the day is fine, the poor superintendant of the clock house can no longer discern the time, and must remain inactive, even though his clock should be so much out of order, as to be half an hour too slow or too fast. In order to accomplish this object satisfactorily, a signal should be given from an observatory, the only place in which the time of the day can be known with certainty at every instant.

To remedy this double inconvenience, and to regulate for the future the town-clocks (of Vienna), he proposes that, commencing from the 1st of March, 1824, the precise moment of noon shall be communi-

cated by a large bell, placed in the observatory for that purpose, in the following manner. Two minutes before noon, the sound of the bell shall give warning for some seconds to inform the superintendants of the public clocks, and all the inhabitants of the town, that it is time to go to their clocks and regulate them. Twenty-four seconds before noon, the same bell to begin striking like a clock, one stroke every two seconds, so that the twelfth and last stroke is the precise moment of noon. Exactly at this last stroke, it shall be previously arranged for the clock of St. Stephen's church to begin striking noon, which will serve as a signal to regulate with axactness all the other public clocks of the town and suburbs. Every inhabitant will likewise be able to avail himself of this opportunity to regulate his own clock.

We think we ought, says M. Littrow, to add two remarks to the preceding. The first relates to the persons to whom the execution of the plan must be principally confided. They have often occasion to know the time almost to a second, and the means which they have hitherto employed effected their purpose badly, or not at all. We are not speaking here of those who, like their predecessors in the last century, make use of solar dials, and other methods equally defective; for such workmen, who are satisfied with knowing the time within a few minutes, must not be confounded with real artists. But there are men of this class, adds Mr. Littrow, and I myself know several, who would rival the most celebrated artists of England, if they received the necessary encouragements. Every English artist has an observatory in his house for his own use; it is with this great celestial clock that he compares his instruments; he corrects and rectifies his work, till he is able to say, with a full conviction to every purchaser who presents himself—"It is ready, it is finished, it is complete."

Our author's second remark relates to the difference which exists between what is called true time and mean time. He here enters into a long digression on measuring time by the moon. The most ancient nations regulated their weeks by this planet and its different phases. Many periods of unequal duration have been invented to calculate centuries and ages, but men have been unanimous in reckoning seven days to the week, the origin of which is lost in remote antiquity. Doubtless at first sight, the moon appears, by its continually changing disk, and its striking phases, to have been made expressly to serve as a perpetual calendar; nevertheless, it will soon be perceived, that, of all the heavenly bodies, it has the least right to this prerogative. In fact the Jews, among whom the moon plays the most important part, have the most confused chronology among the moderns. There are no less than six different kinds of years in use among them, and the learned alone can comprehend their calendar, which is exceedingly complicated. But what shall we say of our own ecclesiastical computation? Are there many people, even among the well-informed, who can tell what day Easter or Whitsuntide will fall upon, in any year?

If the moon is so ill adapted for regulating the calendar, we may

likewise observe that it is not from the sun we can expect an exact division of the day into hours, minutes, &c. In fact, to adopt popular language, the sun moves in an ellipse, in an oval curve. In winter, he is nearer the earth than in summer, and he moves faster in the former season than in the latter. This circumstance alone would create an inequality in the length of the days, as well as in that of the hours, minutes, &c. But there is besides another cause of inequality. The sun moves in the ecliptic, whose plane makes an angle of about 23° 28′ with that of the equator, and it is to this latter circle that we refer the measure of time. In fact all our determinations on this head are founded on the perfectly uniform rotation of the heavens, or rather of the earth, around the axis of the world, that is to say, around the axis of the equator, the direction of which is exactly from south to north. Even were the sun to move uniformly in the ecliptic, for instance, a degree each day, this degree, referred to the equator, would hardly ever correspond to a degree of the latter circle, but would be sometimes more, sometimes less. So that even the motion of the sun at a constantly equal rate would be to no purpose; his motion would be unequal with respect to us, and could not serve to determine the time exactly.

Since the true sun, that king of our days, that dispenser of light and heat, so useful to form great periods of years and centuries, is so little adapted to measure the day and its parts, astronomers have chosen another sun, which assuredly has neither light nor heat, and does not even exist in the heavens, but which is, for that very reason, the better calculated to be the regulator of our clocks. This sun, which is called the mean sun, to distinguish it from the true sun that attracts the eye, moves uniformly in the plane of the equator, so that it completes its annual course in the same time that the real sun traverses the ecliptic by an unequal movement. When this mean sun passes over the meridian of a place, we say that it is mean noon in that place; and often in the course of a year, there is more than a quarter of an hour of difference between this mean noon, and the true noon of the real sun. But as the mean solar days are always of the same length, the mean noon will always be exactly given by the last stroke of the observatory bell, as before explained. In this manner, clocks will no longer be made to go against their nature, that is to say irregularly, but without incessantly altering them, it will be sufficient to see every noon if their movements be regular; and the superintendants of clocks, who have hitherto had no good method of verifying the time to a second, will hereafter have an opportunity of ascertaining daily how far the movement of their pendulums is correct. (*Bul. de Sciences.*)

On Predicting the Weather by the Barometer.

It is now a considerable time since the barometer was proposed as a a proper instrument for predicting the weather; and hence it obtained the name of *weather glass*. Accordingly, rules for this purpose have been given by Dr. Halley, Dr. Hutton, Messrs. Pascal, Patrick, Rowning, Changeux, de Luc, Clarke, Dalton, and many others, from whose writings we have collected the following rules.

When the mercury in the barometer rises, it is a sign of fair weather, attended with heat, if in summer, but frost in winter. If the mercury falls, it denotes rain, or wind, or perhaps both.

If the mercury rises suddenly during the time of rain, the ensuing fair weather will not continue long; but if the rise is gradual, and continues for several days, a continuance of fair weather may be expected.

If the mercury falls suddenly several divisions, it is a sign that the succeeding rain will not be of long duration. But if the mercury continues to fall regularly for several days, rain or wind, or perhaps both, will be of considerable duration.

The mercury falling considerably in autumn, winter, or spring, indicates gales of wind, commonly attended with rain, snow, or sleet; but, in summer, it denotes rain, and probably thunder. The mercury is low with high winds, and still lower if accompanied with rain. If the mercury falls quickly in very warm weather, thunder showers may be expected soon after.

If the mercury be in an unsettled and fluctuating state the weather has the appearance of being very changeable.

If the mercury has been stationary during several days, its surface must be carefully observed, to ascertain whether it is rising or falling. For this purpose, let the exact figure of the surface of the mercury be observed; then shake the tube a little, and observe if the mercury is more or less convex or concave. If it is more convex, it is a sign the mercury is rising; if the same as before, it is stationary; but if less, that it has attained its greatest altitude at that time, and will fall soon. If the mercury was concave before the tube was shaken, and more concave afterwards, the mercury is falling; if of the same concavity, or nearly so, it is stationary; but if less concave it is rising.

Between the tropics, there is little variation in the height of the mercury in the barometer; and the more distant any place is from the equator, the greater is the range of the mercury. Thus, at St. Helena, the extreme variation is very little; at Jamaica it is only about three tenths of an inch; at Naples it seldom exceeds an inch. In England the extreme range amounts to about $2\frac{1}{2}$ inches; and at Petersburgh to $3\frac{1}{3}$ inches nearly.

On the Methods proposed for ascertaining the Longitudes and Latitudes of Places by Magnetical Instruments.

THE facility and readiness with which the longitudes and latitudes of places upon the surface of the earth might be ascertained, by means of magnetical instruments, if their performance could be depended upon, has at various times brought forward the proposals of instruments, and calculations made expressly for the purpose; but the actual experiments made on those plans have constantly shewn, that both the instruments and the calculations are insufficient to answer that object; and the principal reason of the failure is the uncertainty of the motion of the magnetic poles of the earth, upon which the variation of the compass principally depends.

That those poles (which may be considered to be the centres or focuses of all the magnetic bodies contained in the earth) do not remain fixed, but that they do actually move from place to place, is sufficiently evinced by the results of accurate observations; and no modern writer seems to entertain a doubt about it. The variation of the declination, or the change of variation, is principally attributed to the motion of those poles; but the difficulty consists in determining whether this motion is regular or irregular, viz. whether it may, or may not, be foretold by calculation, according to any rule whatsoever.

That nature is regular in her works, and that every natural operation depends upon adequate causes, no person, who is at all acquainted with philosophy, can possibly deny. But when a certain phenomenon depends upon the combination of a variety of causes, some of which, and perhaps all of them, are out of the reach of our senses, and of calculation, we call it irregular or accidental; not for want of a natural dependance upon adequate causes, but because we are unable to discover and ascertain the laws of that dependance. Thus we know that the temperature of the atmosphere in London depends on the time of the year, on the point from which the wind blows, on the clearness of the air, &c. yet no one can foretel the precise degree of heat that will be indicated by the thermometer on a particular day of the next year; because, in the first place, we are not acquainted with all the concurring causes, and secondly, because, from the action of those causes upon each other, their ultimate effect upon the body of the earth becomes the result of an immense and incommensurable combination.

With respect then to magnetism, we must first endeavour to discover the causes which occasion the motion of the magnetic poles of the earth; and secondly, we must consider whether the effects of those causes may or may not be subjected to calculation.

The projectors of the methods for ascertaining the longitude and latitude by means of the variation compass, and of the dipping needle, generally frame hypotheses of regular movements, and establish upon them all their rules and calculations, and overlook the natural causes of irregularity or uncertainty. But hypotheses that are not founded upon a constant coincidence of effects, and especially when

they are insufficient to account for all the phenomena, cannot be considered as guides in the investigation of future events.—The magnetic poles of the earth have been supposed to be four in number; though they are at present generally, and more properly, thought to be only two. They have been supposed to reside on the surface of the earth, and to move upon it at a certain annual rate: They have been supposed to be fixed to a sort of nucleus within the earth, and to move along with it either from east to west, or from west to east: They have been supposed to be in the atmosphere; and in short, the conjectures have been very numerous; but let the hypothesis be what it will, we have no reason to believe that their motion is so regular as to be foretold, which will more evidently appear from the following reasons.

In the investigation of natural properties, when they are out of the reach of actual observation or calculation, the imagination must start with, and be guided by the analogy of, established facts and laws; otherwise the probability of being right vanishes entirely.—Agreeably to this rule, if we attempt to form conjectures relative to the magnetic poles of the earth, we must in the first place say, that as the magnetic polarity has been found to be a property only of iron or ferruginous bodies, therefore it is likely that the magnetic poles of the earth reside not in the atmosphere, but in the ferruginous bodies contained in the earth. Secondly, we have no reason whatever to believe that the earth contains a moveable nucleus or kernel, but we know that in a magnet, whether natural or artificial, the poles frequently change their places, though the magnet has no nucleus; and therefore the magnetic poles of the earth may be susceptible of motion independent of a nucleus. Thirdly, it is natural to suppose that the same causes, which have been found to alter the situation of the poles of a magnet, act in the same manner upon the earth, and occasion the motion of its poles. Those causes, and the method of manifesting their effects, may be reduced to four; viz. the action of one magnet upon the other; the action of heat and cold; the chymical alteration or decomposition of the substance affected with magnetism; and, lastly, the mere mechanical derangement of parts.—That all those causes take place in the earth, no body can deny; and of course it seems to be as evident, as the nature of the subject will admit of, that the motion of the magnetic poles is governed by the concurrence of all those causes.

So far we have considered only the motion of the magnetic poles of the earth, which undoubtedly govern the general variation of the magnetic needle; but if we also take into the account the local causes, which have been indisputably found to affect the needle in particular places, such as the vicinity of great tracts of land, promontories, volcanos, &c. we must acknowledge that the prospect is very discouraging, and the probability of our ever becoming able to ascertain the longitude and latitude by means of magnetical instruments, seems almost to vanish. In fact, when we examine the different projects hitherto published, and compare their results, we find an astonishing diversity as well among themselves, as between them and actual observations.

TABLE

Of the Latitudes and Longitudes of the Principal Observatories in the World, from the latest and most accurate Observations.

Names of Places.	Latitude.	Longitude.	
		In Degrees.	In Time.
	° ′ ″	° ′ ″	h. m. s.
Amsterdam	52 22 17 N	4 53 15 E	0 19 33 E.
Armagh	54 21 15 N.	6 37 30 W.	0 26 30 W.
Batavia	6 9 0 S.	106 51 45 E.	7 7 27 E.
Berlin	52 31 45 N.	13 22 15 E.	0 53 29 E.
Bologna , ...	44 30 12 N.	11 21 30 E.	0 45 26 E.
Bremen	53 4 38 N.	8 48 0 E.	0 35 12 E.
Breslaw	51 6 30 N.	17 2 18 E.	1 8 9 E.
Brunswick	52 16 29 N.	10 32 0 E.	0 42 8 E
Buda	47 29 44 N.	19 2 30 E.	1 16 10 E.
Cadiz	36 32 0 N.	6 17 22 W.	0 25 9 W.
Cambridge (St. M. Steeple)	52 12 43 N.	0 7 34 E.	0 0 30 E.
Cassel	51 19 20 N.	9 35 18 E.	0 38 21 E.
Coimbra	40 12 30 N.	8 24 42 W.	0 33 39 W.
Constantinople (St. Sophia)	41 1 27 N.	28 55 15 E.	1 55 41 E
Copenhagen	55 41 4 N.	12 35 6 E.	0 50 21 E.
Cracow	50 3 38 N	19 57 9 E.	1 19 40 E
Dantzic	54 20 48 N.	18 38 5 E	1 14 32 E
Dorpat	58 22 47 N.	26 42 0 E.	1 46 48 E
Dresden	51 2 50 N.	13 43 1 E	0 54 52 E
Dublin	53 23 13 N.	6 20 30 W	0 25 22 W.
Edinburgh	55 57 57 N	3 10 21 W.	0 12 41 W.
Florence	43 46 41 N.	11 15 45 E.	0 43 3 E
St. Gall (Switzerland) . .	47 25 40 N.	9 22 15 E.	0 37 29 E
Genoa	44 25 0 N.	8 58 0 E.	0 35 52 E.
Glasgow	55 51 32 N.	4 16 0 W.	0 17 4 W.
Gotha (Seeberg) . . .	50 56 8 N.	10 44 0 E.	0 42 56 E.
Gottingen	51 31 50 N.	9 56 30 E.	0 39 46 E.
Greenwich	51 28 39 N.	0 0 0	0 0 0
Hyeres	43 7 2 N.	6 7 55 W	0 24 32 E.
Kew	51 28 37 N.	0 15 45 E.	0 1 3 W.
Leipsic	51 20 16 N.	12 21 45 E	0 49 27 E.
Leyden	52 9 30 N.	4 29 13 E.	0 17 57 E.
Lilienthal	53 8 30 N.	8 54 15 E.	0 35 37 E.
Lisbon	38 42 24 N.	9 8 30 W.	0 36 34 W.
London (St. Paul's) . .	51 30 49 N.	0 5 47 W.	0 0 23 W.
Madrid (Grand Square) .	40 24 57 N.	3 42 15 W.	0 14 49 W.
Malta (Valetta)	35 53 0 N.	14 30 35 E.	0 58 2 E.
Manheim	49 29 18 N.	8 28 0 E.	0 33 52 E.

*

Names of Places.	Latitude.	Longitude. In Degrees.	Longitude. In Time.
	° ′ ″	° ′ ″	h. m. s.
Marseilles	43 17 49 N.	5 22 15 E	0 21 29 E
Milan	45 28 2 N	9 11 31 E.	0 36 46 E.
Mirepoix	43 5 7 N.	1 52 26 E	0 7 30 E.
Mittau	56 39 6 N	22 43 27 E	1 34 54 E
Montauban	44 0 55 N	1 20 45 E	0 5 23 E.
Montpellier	43 36 16 N	3 52 40 E	0 15 31 E.
Moscow	55 45 45 N.	37 33 0 E	2 30 12 E
Munich	48 8 20 N.	11 34 40 E	0 46 18 E
Naples	40 50 15 N.	14 15 45 E	0 57 3 E.
Nuremberg	49 26 55 N.	11 4 15 E.	0 44 17 E
Oxford	51 45 39 N.	1 15 22 W.	0 5 1 W.
Padua	45 24 2 N	11 51 32 E	0 47 26 E
Palermo	38 6 44 N	13 22 0 E	0 53 28 E.
Paris	48 50 14 N.	2 20 15 E.	0 9 21 E.
Pekin	39 54 13 N	116 27 45 E	7 45 51 E.
Petersburg	59 56 23 N.	30 18 45 E	2 1 15 E.
Pisa	43 43 11 N.	10 24 0 E.	0 41 36 E
Plymouth	50 22 20 N.	4 7 16 W.	0 16 29 W.
Portsmouth	50 48 3 N.	1 5 59 W.	0 4 24 W.
Prague	50 5 19 N	14 25 15 E	0 57 41 E.
Ratisbon	49 0 53 N	12 4 30 E	0 48 18 E.
Richmond	51 28 8 N.	0 18 45 W	0 1 15 W
Rome (College) . . .	41 53 54 N.	12 29 17 E	0 49 59 E.
Slough (Herschel's) . .	51 30 20 N.	0 36 0 W	0 2 24 W.
Stockholm	59 20 31 N.	18 3 30 E.	1 12 14 E
Strasbourg	48 34 56 N	7 44 51 E.	0 30 59 E,
Toulouse	43 35 46 N.	1 26 30 E	0 5 46 E.
Turin	45 4 14 N.	7 40 15 E	0 30 41 E
Upsal	59 51 50 N	17 39 0 E.	1 10 36 E.
Utrecht	52 5 31 N	5 7 16 E.	0 20 29 E
Venice (St. Mark's) . .	45 25 32 N	12 20 59 E	0 49 24 E
Verona	45 26 7 N	11 1 15 E	0 44 5 E.
Vienna	48 12 40 N	16 22 45 E	1 5 31 E
Viviers	44 29 14 N	4 41 0 E.	0 18 44 E
Weimar	50 59 12 N.	11 21 0 E	0 45 24 E
Wilna	54 41 2 N.	25 18 0 E	1 41 12 E.

On the Method of determining the Flatness of the Oblate Spheroid in France, by the comparison of an Arc of the Meridian with an Arc of a Parallel.

THE two lines of curvature on the earth's surface at any place, being well calculated to determine with precision the dimensions of the oblate spheroid in that place, geometers and astronomers have long wished that the great geodesic operations executed in Europe, like those upon which the new system of French measures is founded, should be immediately applied to the measurement of different arcs of meridians and parallels, in order to acquire, by this means, a more accurate knowledge of the real figure of the earth.

The trigonometrical labours undertaken by the French royal body of geographical engineers, under the immediate direction of the war department, and which are to serve as the skeleton of the new map of that country, already furnish very valuable results for the solution of the problem in question. For example: an arc of the parallel, measured trigonometrically and astronomically, in the latitude of 45 degrees, extends from the tower of Cordovan into Piedmont, and might even be continued to Fiume and farther. The observations on longitudes made last year, by Colonel Brousseaud and the astronomer Nicollet, by means of signals of fire, give the amplitudes of four consecutive portions of this line, which embrace an extent of seven degrees. They are connected with those made by Messrs. Plana and Carlini, and other foreign philosophers a year before, upon the same line beyond the Alps, and thus form a geographical union between France and Italy.

Another arc of the parallel, not less important, comprised between Brest and Strasburg, the measure of which had been earnestly desired by the illustrious La Place, author of the Mecanique Celeste, is already known geodesically. It is upon this line that reverberating lamps have been constantly used for the purpose of ascertaining whether angular observations in places but little elevated, agree together better by night than by day. It is also upon this line, that a trigonometrical survey has been effected by reciprocal and simultaneous observations from Paris to Brest; with the view either of determining exactly the absolute heights of the stations comprised between these extreme points, or of connecting by these stations all the secondary surveys intended to be afterwards undertaken for forming a hydrographic map of France.

It is proposed this year to make observations on the longitude of this second primordial line; but in order to avoid the trouble of establishing temporary observatories in an open country, and above all, the enormous expense which their construction would occasion, the difference of longitude between the extremities of this axis, will, with the assistance of chronometers placed at several intermediate points, be obtained, by the rapid transmission, by means of gunpowder signals, of the hours which will be counted, at the same instant of time, at Brest, and at Strasburg. This very simple proceeding is

perhaps the best that can be employed to obtain promptly the total amplitude of a great arc of parallel, not only because it is independent of the errors which might result from the ordinary method of absolute time determined at intermediate stations at a short distance from one another, but because it is not liable to the irregularities in the diurnal movement of chronometers. Nevertheless, as it is of importance to compare together different arcs of the same parallel, it will be highly useful to ascertain separately the difference between the meridians of Brest and Paris, and that between the meridians of Paris and Strasburg.

The parallel of the 45th degree, of which we have just spoken, is joined in one direction to one of the sides of the meridian of France, and in the other to the base of Beccaria, near Turin, being verified by the French geographical engineers, as well as by M. Plana, and other Italian philosophers; so that the method laid down by La Place in the third Supplement to his "*Analytical Theory of Probabilities*," might be easily applied for correcting in the most advantageous manner this arc and its several parts, by the difference existing between the entire base measured directly, and its length, as deduced from the chain of triangles.

The calculations relative to the comparison of an arc of the parallel with an arc of the meridian, are capable of being effected in a manner analogous to that made use of for determining the oblateness of the earth, by the measure of two arcs of meridians under different latitudes. In fact, there exists a relation between the length of an arc of the meridian, considered as elliptical, and the latitude of its extremities; and this relation is essentially a function of the radius of the equator, and of the oblateness of the earth. In like manner, an arc of the parallel in any given latitude, is a function of its amplitude, of the radius of the equator, and of the same oblateness; thus, proceeding by the ordinary mode of elimination, we can obtain these two last unknown quantities; that is to say, the dimensions of the oblate spheroid at the point where the two combined arcs cut one another, and consequently can ascertain whether the figure of this solid is the same generally attributed to the whole earth, according to the comparison made of the arcs of meridians measured in France and at the equator.

If the parts of the parallel thus examined are not proportional to their amplitudes, it will be advisable to determine the spheroid which corresponds best upon the whole with the observations of longitude, and this by using the method of the *smallest squares*, invented by M. Legendre, and demonstrated by M. Laplace to be the most advantageous. In this case, conditional equations must be formed between the errors to which observations are liable and the oblateness of the earth; and if among the smallest probable errors which affect the observation of longitude, there should be any too considerable to be really attributable to the observations, it may be concluded that the spheroid sought is not that of revolution. The surest method will then be to have recourse to the admirable theory given in the third book of the Celestial Mechanics of La Place.

The grand trigonometrical surveys undertaken to furnish materials for the new topographical map of France, and the numerous observations of the pendulum carefully collected by the Board of Longitude in that kingdom, concur to throw a new light upon the difficult question of the figure of the earth. And it is to be earnestly hoped that, in other countries besides France, similar exertions in favour of science and public utility will be promoted and patronised.

On the Agency of the Earth in producing Meteors. By Professor MEINECKE.

THIS gentleman, in a memoir read to the Natural Society of Halle, proves, in various ways, the existence of a lower terrestrial atmosphere; he thinks himself justified, by the reasons he alleges, in concluding with certainty, that this atmosphere, which may penetrate to a depth of twenty geographical miles into the interior of the earth, is already compressed at a smaller depth, so that without being liquid, it forms a fluid equivalent to water. Hence there results for the lower terrestrial atmosphere a mass, in comparison of which, the higher atmosphere, which is known to be equal in weight to a column of water, about thirty feet high, appears very small.

It is to this mass of inferior air, contained in the pores of fossils, in cavities, in abysses, and even constituting part of the elements of fossils, that the professor attributes the greater part of meteors; while that insignificant mass of air, disseminated in the form of vapour, and hitherto called the atmosphere, at most contributes but slightly to their creation. As he attributes the barometrical phenomena to the inferior atmosphere, he likewise denies the influence of the moon upon the weather.

On the Colours of the Atmosphere.

IF the earth's atmosphere consisted of a medium unlimited, and perfectly homogeneous, the sun and planets would shine in a firmament of the most intense darkness, similar to what has been observed by travellers on the elevated summits of the Alps and the Andes.

As the atmosphere, however, is of a limited extent, and composed of strata of variable density, the light of the sun which falls upon it is reflected in every direction, and reaches the surface of the earth with that chaste tinge of blue, which forms such a fine relief to the yellowish light of the heavenly bodies.

The blue colour of the sky was attributed by Fromondus, Otto Guericke, Wolfius, and Muschenbroek, to a mixture of light and shadow. Sir Isaac Newton and Bouguer, on the contrary, were of opinion, that the particles of air reflect the *blue* rays more copiously, and transmit the *red*.

This explanation, which was then little better than a mere conjecture, has been rendered highly probable by the experiments of Dr. Brewster on the polarisation of light.

He observed that one of the images of certain parts of the sky, formed by a doubly refracting crystal, was much bluer than the other, and that the images changed their tints alternately. Upon the supposition, therefore, that the light of the sky consists of two portions of light, one blue and the other nearly colourless, we may explain all the phenomena which appear, when the light of the sky is examined in different azimuths, and in different planes passing through the sun.

The phenomena of blue shadows, which have been so often observed, arise from the illumination of the shadows of bodies by the blue light of the sky, the parts without the shadow being illuminated by some other light, such as that of the sun or of a candle. These coloured shadows are generally seen with most distinctness at sun-rise and sun-set, when the sun's light has a yellow tinge.

The colours of shadows illuminated by the sky, vary in different countries, and with different seasons of the year, from pale blue to a violet black; and when there are yellow vapours in the horizon of yellow light reflected from the lower part of the sky, either at sun-rise or at sun-set, the shadows have a strong tinge of green, arising from the mixture of these accidental rays with the blue tint of the shadow.

The phenomena of coloured shadows are often finely seen in the interior of a room. They arise from the blue light of the sky, and the light reflected either from the furniture, or the painted walls of the room.

M. Hassenfratz has written a very elaborate memoir on the subject of coloured shadows, and has deduced the following conclusions from his various experiments and observations.

1. That the shadows formed by the direct light of the sun and that of the atmosphere, vary from a *meadow green* to a *violet black*, in a gradation through the *blue*, *indigo*, and *violet*; and that the variation depends on the intensity of the light of the sun, compared with that of the atmosphere.

2. That the shadows formed in apartments by the light of the atmosphere and reflected lights, may present all the prismatic colours, more or less changed by black.

3. That the shadows produced on a piece of pasteboard, illuminated by artificial light, are reddish and blueish, more or less deep, and, that very probably, the blueish and reddish tints of the shadows, depend on the proportion of hydrogen and carbon in the combustible bodies.

TABLE

For Reducing Sidereal into Mean Solar Time.

Hours.	Equa.	Min.	Equa	Sec.	Equa.
	m. s.		s.		s.
1	0 9 83	1	0·16	1	0·00
2	0 19·66	2	0·33	2	0·01
3	0 29·49	3	0 49	3	0·01
4	0 39 32	4	0 66	4	0·01
5	0 39·15	5	0·82	5	0·01
6	0 58 98	6	0 98	6	0·02
7	1 08·81	7	1·15	7	0·02
8	1 18 64	8	1·31	8	0·02
9	1 28·47	9	1·47	9	0·02
10	1 38·30	10	1·64	10	0.03
11	1 48·13	11	1·80	11	0·33
12	1 57·96	12	1·97	12	0 03
13	2 07·78	13	2·13	13	0·04
14	2 17 61	14	2 29	14	0·04
15	2 27·44	15	2·46	15	0·04
16	2 37 27	16	2·62	16	0·04
17	2 47·10	17	2·78	17	0·05
18	2 56 93	18	2·95	18	0·05
19	3 06·76	19	3·11	19	0·05
20	3 16 59	20	3·28	20	0·05
21	3 26·42	21	4·91	21	0 08
22	3 36·25	22	6·55	22	0·11
23	3 46·08	23	8·19	23	0·14
24	3 55·91	24	9·83	24	0·16

EXAMPLE.

Reduce 8 *hours*, 54 *minutes*, 18·5 *seconds*, *Sidereal Time into Mean Solar Time.*

			m s.
8 hours	. .	Equa. . .	1 18·64
50 minutes	. .	ditto . .	08·19
4 minutes	. .	ditto . .	0 66
18·5 seconds	. .	ditto . .	0·05
Sum	. . . . . .		— 1 27·54
Given time	. . . . .		8h 54 18·50
Mean time required	.		8 52 50·96

TABLE

For Reducing Mean Solar into Sidereal Time.

Hours.	Equa.	Min.	Equa.	Sec.	Equa.
	m. s.		s.		s.
1	0 9·86	1	0·16	1	0·00
2	0 19·71	2	0·33	2	0·01
3	0 29·57	3	0·49	3	0·01
4	0 39·43	4	0·66	4	0·01
5	0 49·28	5	0·82	5	0·01
6	0 59·14	6	0·99	6	0·02
7	1 08·99	7	1·15	7	0·02
8	1 18·85	8	1·31	8	0·02
9	1 28·71	9	1·48	9	0·02
10	1 38·56	10	1·64	10	0·03
11	1 48·42	11	1·82	11	0·03
12	1 51·28	12	1 97	12	0·03
13	2 08·13	13	2·14	13	0·04
14	2 17·99	14	2·30	14	0·04
15	2 27 85	15	2·46	15	0·04
16	2 37·70	16	2·63	16	0·04
17	2 47·56	17	2·79	17	0·05
18	2 57·42	18	2·96	18	6·05
19	3 07·27	19	3·12	19	0·05
20	3 17·13	20	3 28	20	0·05
21	3 26·98	21	4·93	21	0·08
22	3 36·84	22	6·57	22	0·11
23	3 46·70	23	8 21	23	0·14
24	3 56·55	24	9·86	24	0·16

EXAMPLE.

***Reduce** 8 hours, 52 **minutes**, 50·96 **seconds**, Mean Solar Time into Sidereal Time.*

			m. s.
8 hours	. . .	Equa.	1 18·85
50 minutes	. .	ditto	08·21
2 minutes	. .	ditto	00·33
50·96 seconds	. .	ditto	00·11
Sum	. . . .		+ 1 27·53
Given time	. . . . . .		8h 52 50·96
Sidereal Time required	. . .		8 54 18·49

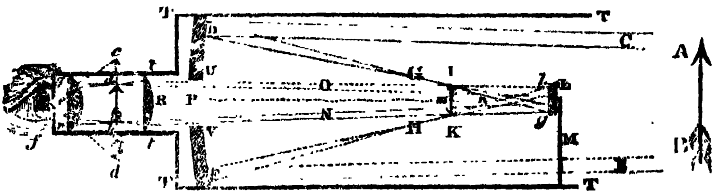
Of the Reflecting Telescope.

THE great difficulty of managing *refracting* telescopes when of great length, and the impossibility of obtaining a higher magnifying power than 500 times, even by making them 600 feet long, stimulated philosophers to attempt a different mode of constructing telescopes, which they have effected by applying the principle of reflection, instead of that of direct vision. By this means instruments of a much shorter length answer the purpose much better; for a *reflecting* telescope, 6 feet long, will magnify as much as a refracting one 100 feet long.

Gregorian Telescope.

THE first telescope of the reflecting kind, which was found to answer the purpose, was invented by Dr. James Gregory, a Scotsman, about the year 1661.

The instrument which he invented is represented by the following figure.



At the bottom of the great tube TTTT is placed the large concave mirror DUVF, whose principal focus is at *m;* and in its middle is a round hole P, opposite to which is placed the small mirror L, concave toward the great one; and so fixed to a strong wire M, that it may be moved farther from the great mirror, or nearer to it, by means of a long screw on the outside of the tube, keeping its axis still in the same line P *m n*, with that of the great one. Now, since in viewing a very remote object, we can scarcely see a point of it but what is at least as broad as the great mirror, we may consider the rays of each pencil, which flow from every point of the object, to be parallel to each other, and to cover the whole reflecting surface D U V F. But to avoid confusion in the figure, we shall only draw two rays of a pencil flowing from each extremity of the object into the great tube, and trace their progress, through all their reflections and refractions, to the eye *f*, at the end of the small tube *t t*, which is joined to the great one.

Let us then suppose the object A B to be at such a distance, that the rays C may flow from its lower extremity B, and the rays E from its upper extremity A. Then the rays C falling parallel upon the great mirror at D, will be thence reflected converging, in the direction D G; and by crossing at I in the principal focus of the mirror, they

will form the upper extremity I of the inverted image I K, similar to the lower extremity B of the object A B: and passing on to the concave mirror L, (whose focus is at *n*) they will fall upon it at *g*, and be thence reflected converging, in the direction *g* N, because *g m* is longer than *g n*; and passing through the hole P in the large mirror, they would meet somewhere about *r*, and form the lower extremity *d* of the erect image *a d*, similar to the lower extremity B of the object A B. But by passing through the plano-convex glass R in their way, they form that extremity of the image at *b*. In like manner, the rays E which come from the top of the object A B, and fall parallel upon the great mirror at F, are thence reflected converging to its focus, where they form the lower extremity K of the inverted image I K, similar to the upper extremity A of the object A B; and thence passing on to the small mirror L, and falling upon it at *h*, they are thence reflected in the converging state *h* O; and going on through the hole P of the great mirror, they will meet somewhere about *q*, and form there the upper extremity *a* of the erect image *a d*, similar to the upper extremity A of the object A B: but by passing through the convex glass R in their way, they meet and cross sooner, as at *a*, where that point of the erect image is formed. The like being understood of all those rays which flow from the intermediate points of the object, between A and B, and enter the tube at T T; all the intermediate points of the image between *a* and *b* will be formed: and the rays passing on from the image through the eye-glass S, and through a small hole *e* in the end of the lesser tube *t t*, they enter the eye *f*, which sees the image *a d* (by means of the eye-glass) under the large angle *c e d*, and magnified in length, under that angle from *c* to *d*.

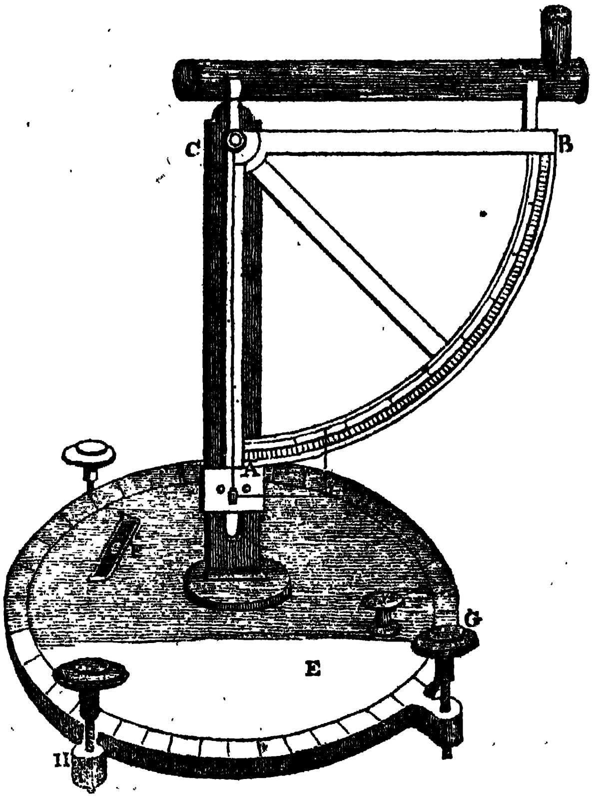
In the best reflecting telescopes, the focus of the small mirror is never coincident with the focus *m* of the great one, where the first image I K is formed, but a little beyond it (with respect to the eye) as at *n*: the consequence of which is, that the rays of the pencils will not be parallel after reflection from the small mirror, but converge so as to meet in points about *q e r*; where they will form a larger upright image than *a d*, if the glass R was not in their way: and this image might be viewed by means of a single eye-glass properly placed between the image and the eye: but then the field of view would be less, and consequently not so pleasant, for which reason, the glass R is still retained, to enlarge the scope or area of the field.

To find the magnifying power of this telescope, multiply the focal distance of the great mirror by the distance of the small mirror from the image next the eye, and multiply the focal distance of the small mirror by the focal distance of the eye-glass: then, divide the product of the former multiplication by the product of the latter, and the quotient will express the magnifying power.

One great advantage of the reflecting telescope is, that it will admit of an eye-glass of a much shorter focal distance than a refracting telescope will; and, consequently, it will magnify so much the more: for the rays are not coloured by reflection from a concave mirror, if it be ground to a true figure, as they are by passing through a convex glass, let it be ground ever so true.

Astronomical Quadrant.

The following figure represents the portable Astronomical Quadrant mounted on an axis and pedestal.



The axis allows us to place the instrument in any vertical position, and the pedestal, moveable in the axis of the circle E F, at the bottom, permits us to place it in the direction of any azimuth, or towards any point of the compass.

The limb A B is graduated into degrees and halves, numbered from A.

Upon the radius C B is fixed a telescope, through which we view any remote celestial or other object. This limb is elevated or depressed by a rack and pinion.

The horizontal circle is graduated into quadrants of 90°, and these again into half degrees, and so on.

The point *Zero* on the quadrant corresponds with Zero on the nonius G.

The quadrant united to the pedestal moves round the limb by means of rack-work and a pinion, F, and shews the position of the place of the quadrant, and consequently of an object.

The *rationale* of this instrument is very obvious; for, by means of it we can measure the angular distance of any celestial body in the zenith; or at any altitude; or of any terrestrial object from any other object in the horizon.

The former is effected by means of the graduated quadrant A B; and the graduated circle E F accomplishes the latter process. Together, these graduations enable us to determine both the altitude and azimuth of a celestial object, since by the compass we can place the instrument due north and south.

On Observing with the Telescope.

THE apparent magnitude of an object, viewed through a telescope, may be measured, with great accuracy, by a scale or by two wires, introduced at the place of the last image, reducing afterwards the angle thus ascertained according to the magnifying power. Care must, however, be taken to avoid as much as possible the distortion which usually accompanies any curvature of the image; and the wires, one of which is sometimes made moveable, by means of a micrometer screw, must be sufficiently illuminated to be distinctly visible. Sometimes a scale is introduced, which, from the apparent magnitude of a known object, such as that of a man of ordinary height, or of a portion of a wall built with bricks of the usual size, enables us at once to read off its actual distance, which is expressed on the scale in hundreds of yards. The angular magnitude of an object, seen through a telescope, may also be found, by viewing at the same time, with the other eye, either a scale, or any other object of known dimensions, placed at a given distance: the lucid disc micrometer of Dr. Herschel is employed in this manner for judging of the magnitude of the celestial bodies. The divided object glass micrometer affords another mode of measurement: the object glass being divided into two semicircular portions, one of which slides on the other; each portion acts as a separate lens, and two images of every part of the object being formed, the angular distance of any two points is determined by bringing their images together, and measuring the displacement of the moveable portion of the object glass, which is required for procuring the coincidence. Sometimes, also, a similar purpose is answered by inserting a divided glass in the eye piece, which is nearly on the same principle, and which seems to be somewhat less liable to error. In a reflecting telescope of Cassegrain's construction, Mr. Ramsden has also produced the same effect by dividing the convex speculum, and causing a part of it to turn round an axis. All these arrangements particularly deserve the at-

tention of those who are employed in practical astronomy and in geography, since the advancement of these sciences much depends on the accuracy of the telescopic and microscopic measures, which are performed by means of optical instruments.

To find the Rate of Time-keepers.

If a Time-keeper could be so constructed as to go uniformly in every season and climate, it would obviate all difficulty respecting the longitude: and though perfect regularity of motion cannot be hoped for in any mechanical contrivance, the want may be in some measure supplied, particularly in short voyages, by ascertaining the rate of a time-keeper; that is, by finding what it gains or loses daily, during a series of observations.

The most general method, as well as the most accurate, of finding the rate of a time-keeper, is by a *transit* instrument, the use of which will be shewn in the next article.

In order to ascertain the mean daily rate of a watch, it should be some days under trial, and the operation is performed either by taking an arithmetical mean between the two extreme daily variations, or between them all together; the latter method seems the most correct: but if the watch should materially alter its rate of going while under trial, all the observations made before the alterations took place must be rejected, and only those retained which were made afterwards. The time generally allowed for ascertaining the mean rate of a watch is about a month.

But some astronomers think that a *rate* deduced from a *long* series of observations is best; while others prefer the *latest rate* taken from a short trial. On such a nice point as this, little can be said with certainty. If, however, the rate is found to be uniform, and the watch be well adjusted for heat and cold, a few days may be sufficient to determine its mean rate; but if this be not the case, several months may be necessary.

With respect to the adjustment for climate, as well as the various precautions necessary in the management of a time-keeper, the maker's directions should be carefully followed.

Of the Transit Instrument.

A Transit Instrument is a telescope placed in the meridian in order to observe the times that the heavenly bodies pass this great circle, and thus (by the help of a sidereal clock) to find their right ascensions; and also, to determine the errors and rates of chronometers.

Across the middle of the telescope is fixed an axis, at right angles to it, the ends of which are tapered into pivots, which turn in notches

made in a frame for this purpose. The axis must be perfectly level and placed east and west, that the telescope may turn in the plane of the meridian.

In order to observe the instant that a celestial object passes the meridian, there is placed in the telescope a system of wires, generally consisting of five, equi-distant from each other, and perpendicular to the horizon; there is also an horizontal wire bisecting the rest. The middle vertical wire is intended to coincide with the meridian; and the *instant* that any heavenly body passes this wire is called its *transit*. The other parallel wires are intended to correct or verify the observation; which is done by taking a mean between the transits over the first wire and the last, or over the second and fourth; or, what is reckoned most correct, a mean of the whole, which is called *the reduction of the wires*.

There are five adjustments principally necessary to a transit instrument, three of which regard the telescope, and two the axis.

1. *The wires should be set perfectly vertical*, which is proved by observing that any distant object, cut by a wire, does not vary on moving the instrument up and down, but keeps in the same position over the wire; otherwise, the wires must be turned about till the adjustment is made.

2. *The telescope should have no parallax.* This is seen by bisecting any distant object with the horizontal wire: and if, on moving the eye up and down a little, the object should appear to separate from the wire, the instrument is said to have a parallax, which must be corrected by placing the object and eye glasses at such a distance asunder, that their *foci* may meet in the point where the wires are fixed: but when the object glass has been properly fixed by the instrument maker, the observer has only to adjust the eye glass.

3. *The telescope should be in collimation.** This is known by observing any object as cut by the meridian wire, and if, on reversing the axis, the object remains cut in the same manner as before, the instrument is in collimation; otherwise, it must be corrected by means of the two small screws in the sides of the telescope; that is by easing one, and screwing up the other, until the error appears one half diminished; and again, by inverting the axis, and repeating the operation, until the adjustment is properly effected.

4. *To level the axis.* This is done by means of a screw placed under one of the notches, which raises or depresses that end of the axis at pleasure; and the true horizontal position is proved by a spirit level.

5. *To bring the telescope into the meridian.* This is performed by an horizontal screw, which moves one end of the axis backward or forward as occasion requires; but to ascertain the meridian with perfect accuracy is a problem of some difficulty as well as importance.

* The line of collimation (i. e. of aiming) is a right line passing from the intersection of the meridian wire with the horizontal, to the centre of the object glass. Or, it may be defined a right line passing through the centre of the telescope, and perpendicular to its axis.

On the Ether of Newton.

We have made the following extract from Sir I. Newton's works, to shew that he was of opinion that there is an ethereal medium or subtle elastic ether which pervades the universe :—

"To proceed to the hypothesis: first, it is to be supposed therein, that there is an ethereal medium, much of the same constitution with air, but far rarer, subtler, and more strongly elastic. It is not to be supposed, that this medium is one uniform matter, but compounded, partly of the main phlegmatic body of either, partly of other various ethereal spirits, much after the manner that air is compounded of the phlegmatic body of air; intermixed with various vapours and exhalations: for the electric and magnetic effluvia, and gravitating principle, seem to argue such variety.

"Is not the heat (of the warm room) conveyed through the vacuum by the vibrations of a much subtiler medium than air?—And is not this medium the same with that medium by which it is refracted and reflected, and by whose vibrations light communicates heat to bodies, and is put into fits of easy reflection and easy transmission? And do not the vibrations of this medium in hot bodies, contribute to the intenseness and duration of their heat? And do not hot bodies communicate their heat to contiguous cold ones, by the vibrations of this medium propagated from them into the cold ones? And is not this medium exceedingly more rare and subtile than the air, and exceedingly more elastic and active? And doth it not really pervade all bodies? And is it not by its elastic force, expanded through all the heavens? May not planets and comets, and all gross bodies, perform their motions in this ethereal medium? And may not its resistance be so small as to be inconsiderable? For instance; if this ether (for so I will call it) should be supposed 700,000 times more elastic than our air, and above 700,000 more rare, its resistance would be about 600,000,000 times less than that of water. And so small a resistance would scarce make any sensible alteration in the motions of the planets in ten thousand years. If any one would ask how a medium can be so rare, let him tell me—how an electric body can by friction emit an exhalation so rare and subtile, and yet so potent?—And how the effluvia of a magnet can pass through a plate of glass, without resistance, and yet turn a magnetic needle beyond the glass?"

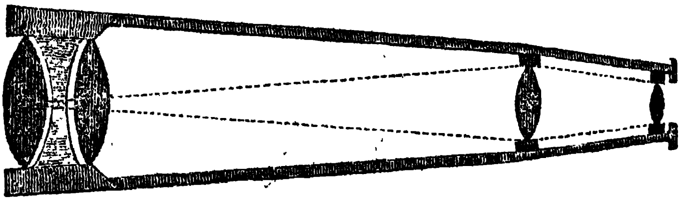
This is a quotation which has been many times made by those philosophers who favour the undulatory theory of light, to show that Newton was not confident in what is generally said to be his own theory, namely, that light is a real substance.

*Achromatic Telescope.**

Achromatic Telescopes differ only from those of the common refracting kind, in the formation and combination of the glasses employed in their construction.

In viewing objects through a refracting telescope, which is not furnished with an achromatic object glass, a kind of aberration is produced, by the different refrangibilities of the various coloured rays of light which form an infinite number of images, neither agreeing perfectly in situation nor in magnitude, so that the objects are rendered indistinct, by an appearance of colours at their edges: this imperfection, however, Mr. Dolland has in great measure obviated, by his achromatic object glasses: the construction of which depends on the important discovery, that some kinds of glass separate the rays of different colours from each other much more than others, while the whole deviation produced in the pencil of light is the same. Mr. Dolland therefore combined a concave lens of flint glass, with a convex lens of crown glass, and sometimes with two such lenses.

The following figure represents an achromatic telescope with a triple object glass, and with Boscovitch's achromatic eye-piece, consisting of two similar lenses, one of which is every way three times as great as the other, their distance being twice the focal length of the smaller.



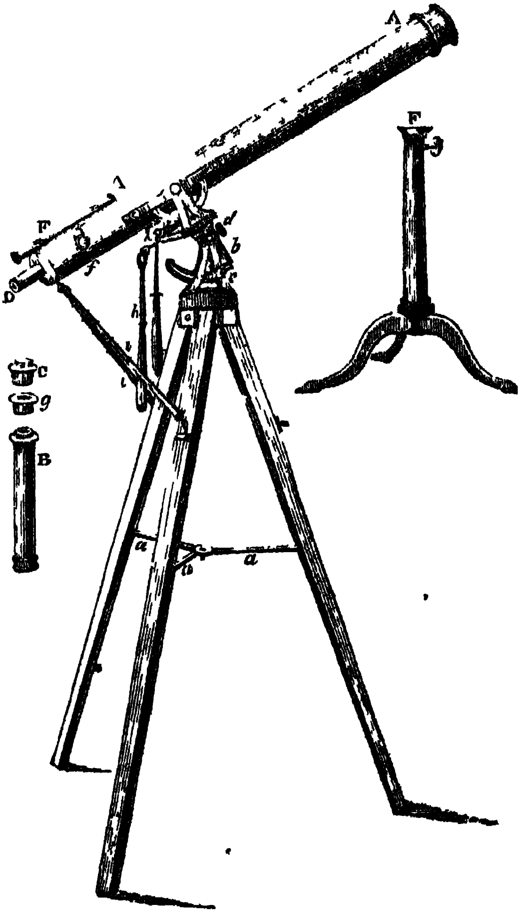
The concave lens of flint glass was sufficiently powerful to correct the whole dispersion of coloured light produced by the crown glass, but not enough to destroy the effect of its refraction, which was still sufficient to collect the rays of light into a distant focus. For this purpose it is necessary that the focal lengths of the two lenses should be in the same proportion, as the dispersive powers of the respective substances, when the mean deviations of the pencils are equal; that is, in the case of the kinds of glass commonly used nearly in the ratio of seven to ten. Sometimes, also, the chromatic aberration, that is, the error arising from the different refrangibilities of the different rays, is particularly corrected in an eye-piece, by placing a field glass in such a manner, as considerably to contract the dimen-

* A *lens* or *prism* is said to be *achromatic*, if it form an image *free from colour*, or if it refracts all the rays of white light to one focus.

A compound lens may be made *achromatic*, or nearly free from colours, if it consists of two lenses formed of substances of different dispersive powers, the one being *convex* and the other *concave*, and having their focal lengths proportional to their dispersing powers.

sions of the image formed by the least refrangible rays, which is nearest to the eye glass, and to cause it to subtend an equal angle to the image formed by the most refrangible rays, this image being little affected by the glass.

The following figure represents one of Mr. Dolland's achromatic telescopes, supported in the centre of gravity, with its rack work motions, and mounted on its mahogany stand,



the three legs of which are made to close up together by means of the brass frame *aaa*, which is composed of three bars, connected together in the centre piece by three joints, and also to the three legs of the mahogany stand by three other joints, so that the three bars of this frame may lie close against the insides of the legs of the mahogany stand when they are pressed together, for the convenience of carriage.

The brass pin, under the rack work, is made to move round in the brass socket *b*, and may be tightened by means of the finger screw *d*, when the telescope is directed nearly to the object intended to be observed. This socket turns on two centres, by which means it may be set perpendicular to the horizon, or to any angle required in respect to the horizon, the angle may be ascertained by the divided arc, and then made fast by the screw *e*. If this socket be set to the latitude of the place at which the telescope is used, and the plane of this arc be turned on the top of the mahogany stand, so as to be in the plane of the meridian, the socket *b* being fixed to the inclination of the pole of the earth, the telescope, when turned in this socket, will have an equatorial motion, which is always very convenient in making astronomical observations.

Fig. 2 in the plate, represents a stand to be used on a table, which may be more convenient for many situations, than the large mahogany stand. The telescope, with its rack work, may be applied to either of the two stands, as occasion may require, the sockets on the tops of both being made exactly of the same size. The sliding rods may be applied to the feet of the brass stand, so that the telescope may be used with the same advantages on one as on the other.

The tube A A may be made either of brass or mahogany, of three and half feet long. The achromatic object glass of three and half feet focal distance, has an aperture of two inches and three quarters.

The larger size is with a tube five feet long, and has an achromatic object glass of three inches and one quarter aperture.

The eye tube, as represented by B, contains four eye glasses, to be used for day, or any land objects. There are three eye tubes, as C, which have two glasses in each, to be used for astronomical purposes. These eye tubes all screw into the short brass tube at D. By turning the button or milled head at *f*, this tube is moved out of the larger, so as to adjust the eye glasses to the proper distance from the object glass, to render the object distinct to any sight, with any of the different eye tubes.

The magnifying power of the three-and-half-feet telescope, with the eye tube for land objects, is forty-five times, and of the five-feet for land objects, sixty-five times. With those for astronomical purposes, with the three-and-half-feet, the magnifying powers are eighty, one hundred and thirty, and one hundred and eighty; and for the five-feet, one hundred and ten, one hundred and ninety, and two hundred and fifty times.

Stained glasses, as *g*, are applied to all the different eye tubes, to guard the eye in observing the spots on the sun. These glasses are to be taken off when the eye tubes are used for other purposes.

The rack work is intended to move the telescope in any direction required, and is worked by means of the two handles at *h*. When the direction of the tube is required to be considerably altered, the worm-screws which act against the arc and the circle must be discharged: then the screw *d* being loosened, the pin of the rack work will move easily round in the socket *b*.

For the more readily finding or directing the telescope to any

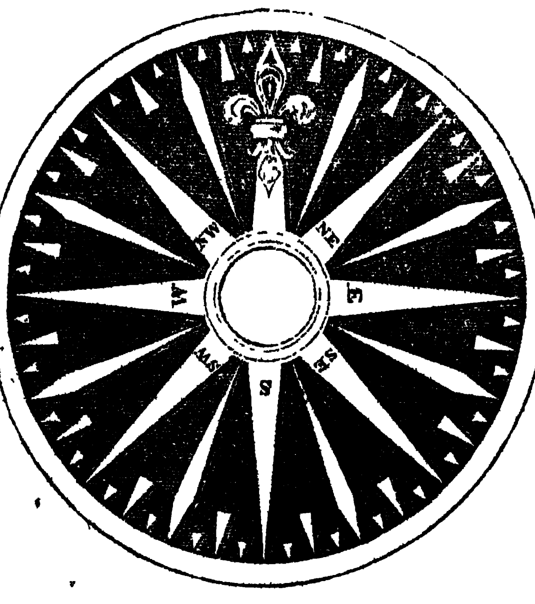
object, particularly astronomical objects, there is a small tube or telescope, called the finder, fixed near the eye-end of the large telescope. At the focus of the object glass of this finder, there are two wires, which intersect each other in the axis of the tube, and as the magnifying power is only about six times, the real field of view is very large; therefore any object will be readily found within it, which being brought to the intersection of the wires, it will then be within the field of the telescope.

In viewing astronomical objects, (and particularly when the greatest magnifying powers are applied) it is very necessary to render the telescope as steady as possible; for that purpose there are two sets of brass sliding rods, *i i*, as represented in the figure. These rods connect the eye-end of the telescope with two of the legs of the stand, by which any vibrations of the tube that might be occasioned by the motion of the air or otherwise, will be prevented, and the telescope rendered sufficiently steady for using the greatest powers. These sliding rods move within one another with so much ease, as to admit of the rack-work being used in the same manner as if they were not applied.

Of the Mariner's Compass.

THE Mariner's Compass is an instrument by which a ship is directed to any intended port. It is also of the greatest use in determining the *bearing* of one object from another.

The following figure is a representation of the card of a *steering* compass, with the names of eight of the points marked; the other divisions indicate half points.



The circumference of the card of the compass is divided into thirty-two equal parts, called *points*; the interval between two adjacent points is, therefore, equal to 11° 15′, and each point is subdivided into quarters. In azimuth compasses, the circumference of the card, besides the usual division into points and quarters, is also divided into 360 degrees; and in some other compasses the quarter of the circumference is divided into 96 equal parts, and hence each division is 56¼ minutes. Four of the points of the compass, namely, N. E. S. W. are called *cardinal* points, being the principal points, and because the names of the others are derived from them.

To the under side of the card, and in the direction of its north and south line, is attached a magnetic bar of hardened steel, of a rectangular form, called the needle, by which means the north end of the card is directed towards the northern part of the horizon; and hence the other points of the compass are directed towards the correspondent points of the horizon.

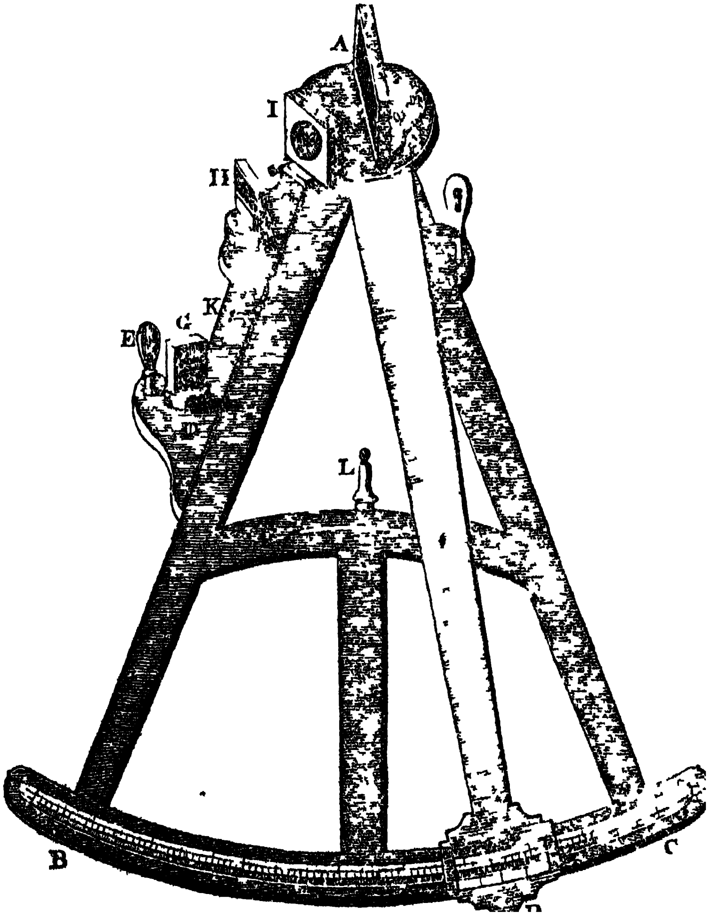
The card and needle are suspended on an upright pin, called the *supporter*, which is fixed to the bottom of a brass or wooden circular box; and the whole is covered with a plate of glass to prevent the wind from disturbing the card. The box has two pins, one on each side diametrically opposite. These pins are let into a brass ring, which is movable, in a square wooden box, on two pins at right angles to the former; by this contrivance, called *jimbals*, the card remains nearly horizontal, although the ship should be considerably agitated Although the card be made to retain an horizontal position at the place where the compass was constructed, yet, when it is carried to any other place where the dip or inclination of the needle is considerably different, it will no longer remain horizontal. In order, therefore, to remedy this, one or two pieces of brass wire, with sliding weights, are placed below the card; and hence, by moving one or both of these weights, the equilibrium of the card will be restored.

Upon the inside of the circular box a black line is drawn vertically, which line is usually called *lubber's point*. The compass should be so placed in the binnacle, that the line, joining the centre of the card and lubber's point, may be parallel to the ship's keel.

Before a compass is used it should be accurately examined. For this purpose it will be necessary to observe if the magnetic axis of the needle corresponds exactly with the north and south line of the card. This may be easily examined if the needle is so constructed as to be capable of reversion. Thus, let the needle be taken from the card, and suspended on a pin, and carefully observe the direction of its axis; reverse the needle, and again observe its direction; then half the difference of these will be the magnetic axis of the needle; and this line ought to coincide with the meridian of the card. Other methods might be proposed to determine the angular distance between the meridian of the card and the magnetic axis of the needle; the easiest of which is by comparing it with a meridian line, truly drawn on a plane; for the difference between the direction of this meridian as shewn by the compass and the known variation is the error.

Description and Use of Hadley's Quadrant

ONE of the most useful and convenient instruments for measuring the altitude of a celestial object, is Hadley's Quadrant, which is represented by the following figure



The form of the instrument is an octagonal sector of a circle, and contains 45°; but, because of the double reflexion, the limb is divided into 90°.

A B, and A C, are the two radii, and B C the circle or limb, which, together with the braces, P Q, form the octant, or frame of

the quadrant; A is the index glass, H the fore horizon glass, and G the back horizon glass, and E F the corresponding sight vanes; I the coloured glass, the stem of which is put into the hole K, when the back observation is used· and L is a pencil for writing down the observation.

The altitude of any object is determined by the position of the index on the limb, when, by reflection, that object appears in contact with the horizon.

If the object whose altitude is to be observed be the sun, and if so bright that its image may be seen in the transparent part of the fore horizon glass, the eye is then to be applied to the upper hole in the sight vane; otherwise, to the lower hole: and, in this case, the quadrant is to be held so that the sun may be bisected by the line joining the silvered and transparent parts of the glass. The moon is to be kept as nearly as possible in the same position, and the image of a star is to be observed in the silvered part of the glass, adjacent to the line of separation of the two parts.

There are two different methods of taking observations with the quadrant. In the first of these the face of the observer is directed towards that part of the horizon immediately under the sun; and is therefore called the *fore observation*. In the other method, the observer's face is directed to the opposite part of the horizon, and consequently his back is towards the part under the sun, and is hence called the back observation. This last method of observation is to be used only when the horizon under the sun is obscured, or rendered indistinct by fog, or any other impediment.

This quadrant was first proposed by Newton, but improved, or perhaps re-invented, by Hadley. Its operation depends on the effect of two mirrors which bring both the objects of which the angular distance is to be measured at once into the field of view; and the inclination of the speculums by which this is performed serves to determine the angle. The ray proceeding from one of the objects is made to coincide, after two reflections, with the ray coming immediately from the other, and since the inclination of the reflecting surfaces is then half the angular distance of the objects, this inclination is read off on a scale in which every actual degree represents two degrees of angular distance, and is marked accordingly. There is also a second fixed speculum placed at right angles to the moveable one, when in its remotest situation, which then produces a deviation of two right angles in the apparent place of one of the objects, and which enables us, by moving the index, to measure any angle between 80 and 90°.

This operation is called the back observation; it is however seldom employed, on account of the difficulty of adjusting the speculum for it with accuracy. The reflecting instrument originally invented by Hooke was arranged in a manner somewhat different.

OF THE CALENDAR.

ALTHOUGH we have completed the systematic part of this work, we deem it necessary to add a short account of the Calendar, on account of its great importance in regulating time, and preserving the seasons and particular days to the same time of the year. And to render the work as complete as possible, we shall also add the method of performing the most interesting and important calculations in Astronomy; which we hope to do in a more simple and intelligible manner than what is to be found in works which profess to treat of this subject more fully than we intend to do.

Having already treated fully of the change of seasons and the regulation of time, we shall only observe here, that the tropical year exceeds the civil year, five hours, forty-eight minutes, forty-nine seconds. Now if this difference were not attended to, the seasons would soon happen in a different time of the year from what they do at present. This circumstance was known long before the real length of the year was ascertained; and to prevent it from taking place, the Romans inserted intercalary days; but without much regularity, till the time of Julius Cæsar, who observed that the year was almost 6 hours longer than 365 days: he therefore added a day every fourth year, which made that year 366 days. This intercalary day was counted the 24th of February, and was called by the Romans, *sexto calendas Martias*, or the sixth of the calends of March; there was, therefore, in that year two sixths of the calends of March, whence it was called Bissextile.

To find Bissextile or Leap Year.

Rule.—Divide the given year by 4; if nothing remain, that year is leap year; but if 1, 2, or 3, remain, it is as many years after leap year.

Example.—Let it be required to find if the year 1825 be leap year, or the 1st, 2d, or 3d after it?

$$1825 \div 4 = 456 \text{ with a remainder of } 1;$$

therefore it is the first after leap year.

Note.—Even centuries not divisible by 4 are not reckoned leap years, such as 1800, 1900, 2100, &c.; but 2000, 2400, &c. are reckoned leap years.

OF THE DOMINICAL LETTER.

It has long been customary to distinguish each day throughout the year by one of the seven first letters of the alphabet; viz. A, B, C, D, E, F, G. The first, A, is affixed to the first day of January, the next, B, to the second; C to the third, and so on to the seventh, G; then A to the eighth, B to the ninth, &c. to the end of the year. By this means we know, that if any letter be prefixed to any day of

the week, the same letter will represent the same day of the week throughout the year. If the 1st day of January, marked by the letter A, be a Sunday, all the other days of the year, which shall have the letter A prefixed to them, will also be Sundays. If the 3d of January, for which the letter C stands, be Sunday, then all the days of the year, marked by that letter, will be Sundays, and for that reason it is called the Dominical or *Sunday Letter*: the following letter will also represent the Mondays, and so on with the others.

As a common year consists of 365 days, or 7 times 52, and one more, it follows that the letter A, which we prefix to the first day of the year, ought also to represent the last, and if it commenced on a Sunday, it would end on Sunday, and of course the next year would begin on a Monday, and the 7th would be Sunday, which is marked by the letter G; that letter will then be the Dominical letter, and as this year began on Monday, it will therefore end with a Monday, and the 3d year will begin on a Tuesday; then the 6th of January, marked F, will be Sunday, and that letter the Dominical letter for the year. In the same way will E become the Dominical letter for the 4th year, D the 5th, and so on in this retrograde order.

If every year consisted exactly of 365 days, in the course of seven years, the same day of the month would fall on the same day of the week; but, as every 4th or leap year consists of 366 days, which is equal to 7 times 52, and two more; therefore if a leap year begin on a Sunday, it will end on a Monday, and the following one will begin on a Tuesday; of course Sunday will fall on the 6th of January, and F will be the Dominical letter for the year after Bissextile, supposing A to have been the Dominical letter for Bissextile.

By means of Bissextile, the order of the Dominical letters is interrupted every 4 years, but again returns after 4 times 7 or 28 years. This is what is called the Solar Cycle, after which the days of the month resume the same order as before. Because every Bissextile consists of 366 days, the intercalary day is added to the end of February, which, in that year, will have 29 days, and therefore the first Dominical letter in March will fall a day sooner than in common years, so that leap year will have two Dominical letters, the one serving to the 29th of February, and the other the remainder of the year.

It is supposed that the Solar Cycle commenced 9 years A. C., and that it was leap year; therefore to find what year of that Cycle any proposed year is; to the given year add 9, and divide the sum by 28, the remainder, if any, is the year of the Cycle, and the quotient shows the number of Cycles since the birth of Christ: if nothing remain, it is the 28th year of the Cycle.

Example.—What year of the Solar Cycle is 1825?

$$1825 + 9 = \frac{1834}{28} = 65 \text{ Cycles, and } 14 \text{ remains,}$$

which is the Solar Cycle.

To find the Dominical Letter.

Rule.—To the given year of our Lord add its 4th part, neglecting any remainders; divide the sum by 7, and the remainder taken from 8, will be the index of the Dominical letter in common years, (remembering that A is 1, B 2, C 3, &c.) but if nothing remain after dividing by 7, then A is the Dominical letter in common years.

In leap years, to this letter is prefixed its preceding one, in the retrograde order which these letters take, which becomes the Dominical letter after the month of February.

Example.—Required the Dominical letter for the year 1825?

Here, 1825 divided by 4 is 456, which added to 1825 is 2281, and this divided by 7, leaves a remainder of 6, which taken from 8, leaves 2 for the index of the letter; therefore B is the Dominical letter for that year.

OF THE GOLDEN NUMBER.

As it is well known that the periodical returns of the Sun and Moon are constantly the same, and that the moon moves nearly 13 times faster than the sun, it follows, that, after a certain number of revolutions, these two bodies will again be in conjunction in the same place of the heavens.

A Greek astrononmer, named Meton, discovered, that the space of time necessary to bring this phenomenon about was 19 years: this period has, on that account, been called the Metonic Cycle, and was very much used by the ancients for determining the times of new and full moon. For, according to that period, the new and full moon ought to happen the same day, and at the same hour of the day, at the end of every 19 years. Therefore, if the day and hour of any *new* or *full* moon be known in the interval of 19 years, all the new and full moons, for the preceding and following years, will be known.

At the time of the Council of Nice, where the question of fixing the Feast ofEaster was discussed, this cycle, of which they made so much use, served as the foundation of their computations. They had found by observation, that in the first year of the cycle the new moons happened on the 23d of January, 21st February, 23d March, &c. opposite to these days, in the calendar, they wrote 1. They had also found, that, in the second of the cycle, the new moons happened on the 12th January, 10th February, 12th March, &c. opposite these they wrote 2; and so on for the other years of the cycle. By this means the year of the cycle being given, they found, by inspection, all the new moons of that year, in the same column of the calendar; and, on account of the great use of those numbers, they were written in characters of gold. Hence the year of the cycle has received the name of the Golden Number.

To find the Golden Number.

Rule.—To the given year add 1; divide the sum by 19. The

quotient is the number of cycles elapsed since the commencement of the Christian era, and the remainder will be the golden number from the last cycle.

Example.—Required the golden number for the year 1825?

$$\text{Then } 1825 + 1 = \frac{1826}{19} = 96 \text{ cycles, and 2 remains,}$$

which is the golden number.

As the solar year exceeds the lunar year by $10^d\ 21^h\ 0'\ 11''$, or nearly 11 days, these intercalary days are named the Epact.

The epact is nothing when the golden number is 1. It is 11 when the golden number is 2; 22, or twice 11, when the golden number is 3; and when the golden number is 4, the epact is 3 times 11, or 33, or rather 3, because, when the number is more than 30, the *excess* is called the epact.

To find the Epact

Rule.—From the golden number of the given year subtract 1, multiply the remainder by 11, and divide the product by 30, if it exceeds that number; the remainder will be the epact.

Example—Required the epact for the year 1825, the golden number being 2;

$$2 - 1 = 1 \times 11 = 11, \text{ and therefore 1 is the epact.}$$

If the epact, for any year, be subtracted from a mean lunation, or $29^d\ 12^h\ 44'\ 3''$, the remainder will be the mean new moon in January for that year; and as that month consists of 31 days, or a day and a half more than a mean lunation, if to the epact we add this day and a half, and subtract the sum from a mean lunation, as above, we shall obtain the time of new moon in February; and as that month, in common years, consists of 28 days, the months of January and February together make 59 days, or very nearly two lunations, the new moon in March will therefore fall nearly at the same time of that month, as in the month of January. By augmenting the epact in this manner, by the excess of each month above a mean lunation, and retrenching from that sum a lunation, or $29^d\ 12^h\ 44'\ 3''$, we shall have the mean new moon for every month in the year. Likewise, by adding half a lunation, or $14^d\ 18^h\ 22'$ to the day of new moon, we shall have the day of *full* moon. But, to avoid fractions, we generally give 30 days to a lunation or synodic period, and add nothing to the epact for January and 2 for February. For March we add 0, for April 2, for May 2, June 3, July 4, August 5, September 7, October 8, November 9, and for December 10.*

This method will not differ above half a day from the time of the true conjunction, and often agrees very nearly; therefore it may be accounted sufficiently exact for ordinary purposes. In the same manner, we add 15 days to have the day of the following *full* moon.

* These numbers are termed the numbers of the month.

For example, the epact for 1814 was 9, which subtracted from 30, leaves 21 for the day of new moon in January and also in March For February, we add 2 to the epact, and take 11, the sum, from 30· and there remains 19, the day of new moon in February. For April, we add 2, and take the sum from 30, and the day of new moon for April is the 19th. For May, we add 2, and the new moon is the 19th, and so on.

As the epact of any year determines the number of days elapsed from the last new moon to the first day of that year, if we wish to know the moon's age on any day of any month, we only need to add the number for that month, as given above, the epact, and day of the month into one sum, and if it be less than 30 it be the moon's age on that day, but if the sum exceed 30, that quantity must be retrenched.

To find the Time of the Moon's Southing.

As the moon, at a mean rate, comes to the meridian 49 minutes later on any day than the preceding day, multiply her age by 49, and the product is the time of her southing in minutes; or multiply her age by 4, and divide by 5, the quotient is the hours, and the remainde multiplied by 12, the minutes when she is south, or on the meridian.

To find the Time of high Water at a known Place.—Common Method.

Rule.—To the time of the moon's southing add the time that it is high water at the given place on the days of full and change, the sum, if under 12, is the hour of high water in the afternoon of that day; if it exceed 12, subtract $12^h\ 24'$; from this again take 24 minutes, and it will be the time of high water in the forenoon of the given day. It is however necessary to remark, that this method is only an approximation, and may, on some occasions, be an hour, or even an hour and a half, wrong.

CYCLES, EPOCHS, &c.

If we multiply the solar and lunar cycle together, that is 28 and 19, we shall have a third period of 532, which is called the Victorian or Dionysian Period. At the end of the above number of years, not only the new and full moons return to the same days of the months, but to the same day of the week, and also the same Dominical letters, and all the moveable feasts return in the same order. On this account it is called the Great Pascal Cycle.

To find the year of the Victorian Period answering to a current year, because the birth of Christ happened in the 457th year of that period; to the year of our Lord add 457 years, and divide the sum by 532, the remainder will be the year of the period.

Example.—Required what year of the Victorian Period the year 1825 was?

$1825 + 457 = \frac{2282}{532} = 4$, and there remains 154, the year of the Victorian Period.

Besides the cycles of the sun and moon, the Romans employed another cycle, which they called the Cycle of Indiction. It was a period of 15 years, but had no respect to the movement of any of the heavenly bodies. It is believed that it was established to exact certain tributes or taxes of the provinces.

The Emperor Justinian ordered that it should be observed or noticed in the public acts; and the Popes still use it in their Bulls, and they fix the commencement of it to the calends of January, but the Romans gave it another epoch. The fourth year of this cycle corresponds to the first of the Christian era; therefore, to find what year of the cycle corresponds to any given year of the Christian era, add 3 to the given year, and divide the sum by 15, the remainder is the year of Indiction.

Example.—What year of the Indiction was the year 1825?

$$1825+3=\frac{1828}{15}=121, \text{ and 13 remains for the year of Indiction.}$$

OF PERIODS AND EPOCHS.

The continued multiplication of the solar, lunar, and indiction cycles, that is, 28, 19, and 15, gives what is called the Great Julian Period* of 7980 years, which is supposed to have commenced 764 years before the creation, and that then the three cycles began at the same time. It is not yet completed, and it comprehends all the other periods, cycles, and epochs. There is not more than one year in all the period that has the same number for the three cycles, and therefore if historians had marked the three cycles in their annals for every year, there could have been no dispute respecting the time that any event happened. The birth of Jesus Christ took place in the 4713th year of the Julian Period. Therefore, to find what year of that period corresponds to any current year, add 4713 to the given year, and the sum is the year of the Julian Period. In this manner, the year 1825 will be found to be the 6538th year of the Great Julian Period.

These are the *principal periods*; but there are others less used, such as the year of Jubilee among the Jews, which was composed of seven years of Sabbaths, and returned in about 49 or 50 years.

The Olympiads among the Greeks, which consisted of four years; and the great Platonic Year, so celebrated among historians, which contained the entire revolution of all the stars from the point from whence they set out to the same again.

As there are in the heavens certain fixed points from which astronomers begin their calculations, historians have also other fixed points which they call eras or epochs, from whence they set out in fixing the time of any event.

The most ancient of these is the Creation of the World, the next is that of the Deluge, 2956 years before the birth of Jesus Christ;

* From Julius Scaliger, its Inventor.

the third is that of the Olympiads, which began in Greece 776 years before Christ, in the 3938th year of the Julian period, the solar cycle being then 18, the lunar cycle 5, and the Roman indiction 8. The next remarkable epoch is that of the foundation of Rome towards the end of the third year of the 6th Olympiad, 753 years before Jesus Christ, in the 3961st year of the Julian Period, the cycle of the sun being then 13, the cycle of the moon 9, and the indiction 1.

The next in order of time is that of Nabonassar, king of Babylon, so famous in astronomy. It has been employed by Ptolemy, Albategnius, Alphonso, Copernicus, and many others, as the most proper era for calculating the motions of the stars. It began, according to Ptolemy, in the 4th of the calends of March, on a Friday, 747 years before Jesus Christ, in the year 3967 of the Julian Period, the first year of the 8th Olympiad, the solar cycle being 19, the lunar cycle 15, and the indiction 6.

After this epoch we have that of Alexander the Great, 424 Egyptian years after the commencement of the era of Nabonassar, for Alexander died at Babylon in the 33d year of his age, the first year of the 114th Olympiad, on the 3d of the month *Desii*, according to some historians, but according to others, on the 23d or 27th of the Julian calendar, which is the 20th of May according to the one, and the 9th or 23d June according to the other, and according to some the 25th July.

But the astronomers who have employed those epochs, as Albategnius and others, fix it to the 12th of November, a Sunday at midday, the first day of the Egyptian month Thoth, 324 years before Jesus Christ, in the 4390th year of the Julian Period, 279 years before the commencement of the Julian Epoch, and 424 complete Egyptian years after the commencement of the era of Nabonassar.

The era of the Syrians and Chaldeans began in the reign of Seleucus Nicator, who succeeded Alexander the Great, and reigned in Syria and in part of Africa, after the death of Alexander the Great. The Julian epoch, adopted by Julius Cæsar, began on the 1st of January of the year of the Confusion, which is found to have been on a Tuesday. This prince, seeing that the year established by Numa Pompilius, the second king of Rome, consisted only of twelve lunar months, and that such a division of the year did not accord with sun, ordered, in the fourth year of his consulship, 708 years after the foundation of Rome, in the 731st year of the Olympiads, 45 years before the birth of Jesus Christ, that, in future, the year should consist of 365 days 6 hours, which was afterwards, and is still, called the Julian Year.

The Spanish Era began in the reign of Augustus, in the 7th year of the Julian Era, 38 years before Jesus Christ, 715 years after the foundation of Rome, and in the 738th year of the Olympiads. It is said it was occasioned by the division of the empire. Spain was given to Augustus, and when he first took possession, to render that day memorable, it was fixed upon for an epoch, and computed from afterwards, *Ab Exordio Regni Augusti* These four words were afterwards abridged, and reduced to the initial letters. This, accord-

ing to some authors, was the origin of the word AERA, which now serves to mark the epoch from whence years are reckoned.

The next epoch following in the order of time, the most renowned, and the best known of any, is the Incarnation of our Lord Jesus Christ, which, on that account, is called the Christian Era.

It began the first minute after the 31st December immediately after his *birth*, which was on a Saturday, in the 4714th year of the Julian Period, 753 years after the foundation of Rome, in the 747th year of Nabonassar, and 324 years after the death of Alexander the Great, the solar cycle being 10, the lunar cycle 2, and the Roman indiction 4.

There are other periods less used, as that of the Emperor Dioclesian, beginning on the 21st April, in the 284th year of Jesus Christ, and 4997 of the Julian Period. There is also the Epoch of the Ethiopians, of the Abyssinians, and of the Martyrs, because of the great persecution that the Christians suffered in that reign.

There is also the Epoch of the Turks, which is called the Hegira, and which began with the *Flight of Mahomet* from Mecca to go to Gabriel, on Tuesday the 16th July, in the 622d year of the Christian Era, at which time Mahomet preached and spread his *false doctrine*.

That of the Persians is named the Jesdegird, from the name of one of their kings, who died on Wednesday the 16th July, in the 632 year of the Christian Era.

The Jews, in their Calendar, reckon the creation of the world to have taken place 3760 years before the Christian Era.

To Draw a Meridian Line.

UPON a plain board, set parallel to the horizon, describe several concentric circles; in the centre of these fix a gnomon, or stile, exactly perpendicular to the plane of the board, and of such a height as the shadow of it may fall upon the circumference of all the circles at different times of the day: mark the point where the top of the stile falls in the forenoon, which will be on the circumference of one of the circles; then watch the time when the shadow falls on the same circle in the afternoon; and a line drawn from the centre or stile bisecting the distance between these points will be in the direction of the true *meridian*.

The reason of several circles being drawn, is to observe the shadow of the stile on any of them, in case the sun should not be shining out in the afternoon, when he would throw a shadow on the same circle; and also to perform the same operation with each circle, in order to ensure accuracy, by taking the mean of the observations.

The best time of the year for doing this, is about the time of the summer solstice, when the daily difference of declination is least. The reason of this opposition may easily be perceived—for at equal distances from the meridian, the sun will have equal altitudes, and, of course, the shadow of any object will have the same length.

Of finding the Latitude of a Place.

THE latitude of any place is equal to the altitude of the pole above the horizon of that place; therefore the poles will appear in the horizon of a place which has no latitude, or that is on the equator.

This problem is nothing else, than finding the elevation of the pole above the horizon; but as there is no star exactly in the pole of the heavens, take any star which is not more than 8° or 10° from the pole, and observe with a quadrant its greatest and least meridianal altitudes; then if both observations are on the same side of the zenith, *half* the *sum* of the altitude is the latitude. If the observations are on different sides of the zenith, half the *difference* of the altitudes is the co-latitude.

Note.—There will be about twelve hours between the observations.

Of the Magnitude of the Earth.

To find the magnitude of the earth is a problem of such importance in astronomy, that it has been attempted by some of the ablest mathematicians, in almost every age, since the days of Eratosthenes to the present. The French mathematicians, by connecting a series of triangles, have lately measured the distance from Dunkirk to Formentera, which corresponds to an arc of the meridian, of 12° 22′ 13″·395; and from this extensive base the circumference of the earth is computed to be 24,855·42 English miles.

A degree of the meridian has been measured in different latitudes, by several astronomers, in order to ascertain the true figure of the earth, as well as to determine its magnitude. Mapertius, along with some other mathematicians, measured a degree in Lapland, at lat. 66 20′, and found it 57,438 toises.

Another, by La Hire, at latitude 49° 22′, which was found to be 57,074 toises.

			Toises.
By Cassini and La Caille, at latitude	45°	=	57050
By ——— (Pennsylvania) lat.	39°	=	56888
By Boscovich	43°	=	56979
By Juan and Ulloa . . .	33° 18′	=	57037
By Dolumbert (France) . .	46° 12′	=	57018
By Bouguer (Equator)	.	=	56753
By De la Condamini . . .	.	=	56749

A Toise is = 1·06577 fathoms.

By comparing these numbers with each other, and taking the arithmetical mean of the whole, the equatorial axis is to the polar, as 230 to 228·92974, which is nearly what Sir I. Newton made it by calculation long before.

From this it is plain the earth is not exactly spherical, but is a kind of oblate spheroid, flattened at the poles.

This proportion makes the equatorial axis exceed the polar by about 34 miles, but some think this statement rather exceeds the truth, and give the compression at $\frac{1}{308.65}$ = 25·66 miles.

The method of performing the operation of measuring a degree of the meridianal arc, and its corresponding arc of the earth's surface, is abundantly simple in theory, although there is scarcely any operation more difficult in execution. It is performed by measuring a base line as nearly as possible in the direction of the meridian, then finding exactly the difference of latitude between the extremities of the base line. Then, as the difference of latitude or celestial arc is to the measured base line, so is one degree of the celestial arc to the length of a degree of the earth's surface, in the same measure as the base line was taken.

In a similar manner may the circumference of the earth's orbit be obtained from knowing the sun's parallax: thus,

$$8\tfrac{2}{3}'' : 360^\circ : \overset{\text{smd.}}{1} :: \overset{\text{semids.}}{149538},$$

the circumference of the earth's orbit.

To find the distance of the sun and earth; then

$$3{\cdot}1416 \times 2 : \overset{\text{smds.}}{149538} :: 1 : \overset{\text{semids.}}{23799{\cdot}8},$$

the earth's distance from the sun.

From the above dimensions of the earth, it appears that one degree on the globe is nearly $69\frac{1}{2}$ English miles.

The length of a degree may be found, very nearly, by the following theorem.

Let L = the latitude, then 60761—(295·75) co-sine 2 L* will be the length of a degree.

Example.—Required the length of a degree of the meridian, at latitude 51°? Here the co-sine of the latitude is ·6293, which multiplied by 2, and by the number 295·75, gives 370, which subtracted from 60761, leaves 60392 fathoms for the length of a degree of the meridian, at latitude 51°.

To find the Obliquity of the Ecliptic.

Rule.—Let the meridian altitude of the sun's centre be observed, on the days of the summer and winter solstices; the difference of those altitudes will be the distance of the tropics; and half that distance will be the obliquity of the ecliptic.

Rule 2.—Or if the latitude of the place be known, the meridian altitude of the sun, at the summer solstice, lessened by the co-latitude, will give the obliquity of the ecliptic.

The obliquity of the ecliptic for the year 1825, is 23° 27′ 44″. By comparing ancient observations with what have lately been made, it appears that the obliquity is decreasing at the rate of $\frac{1}{2}''$ annually.

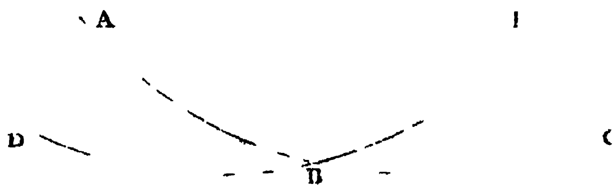
Remark.—By this last rule the declination of a fixed star may also be determined.

* The number 60761 is the radius of the globe, at latitude 45°, in fathoms.

To find the Time of an Equinox.

AT a place, the latitude of which is known, let the sun's meridian altitude be taken the day before the equinox is expected to happen, and also the day after, then the difference between those altitudes, and the co-latitude, will be the sun's declination on those two days when the altitudes were taken.

If either of the altitudes be equal to the co-latitude, that observation was made at the time of the equinox If not proceed thus:



Let A B C be a portion of the equator, and D B E an arc of the ecliptic, D the place of the sun at the first observation, E his place at the second, and B the equinoctial point; also, A D the declination at first observation, and E C at second; then in the right angled spherical triangles, A B D and E B C, there are given the obliquity of the ecliptic, and the declination A D and E C, to find the sides D B and E B, which being found, are to be added together: then say, D B + E B is to D B, so is 24 hours to the time between the first observation and the moment the sun entered the equinoctial point.

To find the Periodic Time of a Planet.

THIS is best done when the planet has no latitude, or in the ecliptic, it will then be in one of its nodes, this time is to be carefully noted, and compared with the time when the planet has a like position, both in latitude, longitude, right ascension, and the line of its apsides. If the planet has only performed one revolution, the interval betwixt the two observations will be the periodic time of the planet; but if it has performed more revolutions, the interval is to be divided by the number of revolutions, and the quotient will be the periodic time. From this it is evident, the greater the interval, or the greater the number of revolutions, the more accurately will the periodic time of the planet be found.

In this manner the length of the tropical year is found to be 365^d 5^h $48'$ $48''$; the sidereal year 365^d 6^h $9'$ $11''$, and the anomalistic year 365^d 6^h $14'$ $2''$.

The tropical year being shorter by $20'$ $23''$ than the sidereal, shows that the sun has returned to the same point of the ecliptic, before he

has made one entire revolution with regard to the stars: consequently, every point of the ecliptic must have moved backward, or in *antecedentia*, and this motion is called the precession or recession of the equinoxes.

The quantity of the recession may be found as follows: $365^d\ 6^h\ 9'\ 11''$: $360°$ :: $20'\ 23''$: $50\frac{1}{4}''$ the recession of the equinoxes annually, which maks one degree nearly in 72 years; so that in about 2160 years these points change a whole sign in the zodiac, and in 25,920 years will go entirely round the heavens, and perform what is called the grand celestial period.

A sidereal revolution being performed sooner by $5'\ 51''$ than the anomalistic, shows that the line of the apsides has a motion in *consequentia*; for, $365^d\ 6^h\ 9'\ 11''$: $365^d\ 6^h\ 14'\ 2''$: $5'\ 51''$ :: $15''$, the yearly quantity by which the sun's apogée is advanced with respect to the stars: and as the equinoxes move $50\frac{1}{4}''$ in antecedentia, and the apsides in $15''$ consequentia, their sum $(65\frac{1}{4}'')$ is the motion of the apsides from the equinoxes.

The periodic time of the moon, (sometimes called a periodic or lunar month,) is the time which she takes to revolve from any point of her orbit to the same again is $27^d\ 7^h\ 43'$.

A synodical month, or the time which the moon takes in passing from one conjunction with the sun to another, is found to be $29^d\ 12^h\ 44'\ 2{\cdot}8''$, being $2^d\ 5^h\ 1'\ 2{\cdot}9''$ longer than the periodic month.

This difference arises from the earth's motion in her orbit; for while the moon is passing from one conjunction to another, the earth will have advanced considerably in her annual course; therefore, the moon must advance as much more than one revolution as the earth has done since the last conjunction, before she be again in conjunction with the sun.

To find the Sun's place in the Ecliptic, or his Longitude.

Having the sun's declination and the obliquity of the ecliptic, his longitude and right ascension can easily be found, and tables formed which will give his place in the ecliptic, answering to his declination, for every day in the year. Thus, to find the sun's longitude, the rule or analogy is as follows:

As sine obliq. eclip. is to sine declination, so is radius to sine sun's longitude.

To find the sun's right ascension the analogy is this:

As tan. ob. eclip. is to tan. declin. so is radius to co-sine right ascension.

To find the Right Ascension of the Stars.

Having the sun's place in the ecliptic, and a well-regulated clock. The clock being adjusted to sidereal time, when the sun is on the meridian, point the hand to the moment from whence the time is to be reckoned; and observe when the star comes to the meridian

then mark the hour and minute that the hand shews on the clock. The time described by it, turned into degrees and minutes of the equator, will be the difference between the right ascension of the sun and stars. This difference being added to the right ascension of the sun, will give the right ascension of the star. The right ascension of one star being known, that of any other may be obtained by it. This is done by marking the time upon the clock, between the arrival of the star at the meridian whose right ascension is known, and the other star whose right ascension is to be found. This time, converted into hours and minutes of the equator (or mean time), will be the difference of right ascensions; hence, by addition or subtraction, the right ascension of the star required is found.

The right ascension and declination of any star being known, its latitude and longitude may be found; and hence, catalogues may be formed of all the stars that are visible in the heavens.

*To find the greatest Equation of the Centre.**

THE equation of the centre of any planet, means the difference of the radius victor moving in a circle, and as moving in the planet's orbit: or it is the difference between the true and mean anomaly. And as these are no where the same, but when the planet is in its perihelion or aphelion, their difference is called the equation to the centre; which is greatest when the sun is at his mean distance from the earth. Therefore, find the sun's longitude when he is at his mean distances from the earth, which is about the beginning of October and the end of March; then the difference of longitude will be the sun's true motion in that interval of time. Find, also, his mean motion for that interval of time: then half the difference between the true and mean motions will be the greatest equation of the centre. The sun's *mean* motion for any interval of time, may be found by multiplying his daily motion, $59' \, 8''\cdot985647$ of a day, by the days and parts of day in that interval.

Or say, $365^d \, 242264 : 360^\circ :: a^d : x^\circ$; if the time be reckoned from 1st of January, it will be the sun's mean anomaly; but if from Aries, it will be his longitude, as under:†

Example.—To find the greatest equation to the centre.

In the year 1824, October 1st, at $23^h \, 49' \, 12''$, mean time, the sun's longitude was $6^s \, 9^\circ \, 32' \, 6''$, and in 1825, March 29th, at $0^h \, 4' \, 56''$, mean time, his longitude was $0^s \, 8 \; 50''\cdot27$; therefore the true difference of longitude is $5^s \, 29^\circ \, 18' \, 27''$, and the interval is $178^d \, 0^h \, 15' \, 38''$, now $365\cdot242264 : 360^\circ :: 178^d \, 01085648 : 175\cdot45584 = 175^\circ \, 27' \, 20''$ mean motion; and $179^\circ \, 18' \, 27'' = 5^s \, 29^\circ \, 18' \, 27''$

$$\begin{array}{r} 175 \quad 27 \quad 20 \\ \hline 2) \quad 3 \quad 51 \quad 7 \\ \hline 1^\circ \; 55' \; 38'' \end{array}$$

The greatest equation to the centre, according to these observation

* This is called the Keplerian Problem.

† Here a is the interval, and x the mean motion.

To find the Equation of Time.

HAVING already given some account of the difference between mean and apparent time, we shall here show the manner of calculating that difference. As we have already said, it arises from two causes, and therefore consists of two parts, which being rightly put together forms the absolute equation. One of these causes is the obliquity of the ecliptic to the equator; and the other is, the unequal motion of the earth in her orbit. The greatest part of the equation is that which arises from the former of these causes, and is found by converting the difference between the sun's longitude and his right ascension into time. His longitude and right ascension may both be found from tables, or from his declination and the obliquity of the ecliptic, by solving a right-angled spherical triangle, and hence their difference or this part of the equation may be obtained.

That part of the equation arising from the unequal motion of the earth, in different parts of her orbit, is found by taking the difference of the mean and true anomalies, or the equation to the centre, and converting it into time, which is the second part of the equation; and is to be added to, or subtracted from, the other part, according as they have like or unlike signs, in order to form the absolute equation. The proper sign is affixed to each of these quantities, by considering whether the mean time is preceded by the apparent, or is preceded by it.

While the earth is going from her aphelion to her perihelion, the apparent time (depending on this cause) will be before the mean, and therefore this part of the equation must be subtracted from the apparent, in order to gain the mean time. But in the other semicircle of her orbit it will be after it, and therefore must be added to gain the mean.

From the 14th April to the 15th June, and from the 13th August to the 23d December, that part of the equation depending on the obliquity of the ecliptic, is also to be subtracted from the apparent (for the apparent is then before the mean); but from the 15th June to the 31st August, and from the 23d December to the 14th April, it is to be added to the apparent in order to gain the mean.

The earth's daily motion in apogee, or at her greatest distance from the sun, is 57′ 12″; but in perigée, or at her nearest distance, it is 61′ 12″. Accordingly, we have the summer longer than the winter by eight days, for she is 8 days longer in passing through the northern half of her orbit than the southern.

Of Solar and Sidereal Time.

A SIDEREAL day is the interval between two successive transits of a star over the meridian. This interval is uniform, for all the fixed stars, make their revolutions in equal times, owing to the uniformity of the earth's diurnal rotation about its axis.

The sidereal day is shorter than the mean solar day by $3' 56''\cdot 55$. This difference arises from the sun's apparent annual motion from west to east, which leaves the star as it were behind. Thus, if the sun and a star be observed on any day to pass the meridian at the same instant, the next day, when the star returns to the meridian, the sun will have advanced nearly a degree easterly, (which is his daily portion of the ecliptic) and as the earth's diurnal rotation on its axis is from west to east, the star will come to the meridian before the sun; insomuch, that, at the end of the year, it will have gained a day on the sun, that is, it will have passed the meridian 366 times, while the sun will have passed it but 365 times.

Now, as the sun appears to perform his revolution of 360° in a year, or $365^d\ 5^h\ 48'\ 48''$: 360 :: 1^d : $59'\ 8''\cdot 3$, which is the space the sun would describe in a day, if all the days were of an equal length; and this space reduced to time is $3'\ 56''\cdot 55$, the excess of a mean solar day above a sidereal day.

Hence, it appears that the earth describes about its axis an angle of $360^\circ\ 59'\ 8''\cdot 3$ in a mean solar day, and an angle of 360° in a sidereal day; therefore, as $360^\circ\ 59'\ 8''\cdot 3$: 24^h :: 360° : $23^h\ 56'\ 4''\cdot 09$, the length of a sidereal day in mean solar time, or the interval between two successive transits of a star over the meridian.

Hence, the following general rule for converting sidereal into mean time, and the contrary.

Rule.—As 24^h : $23^h\ 56'\ 4''\cdot 09$ :: any portion of sidereal time to its equivalent in mean time.

And as $23^h\ 56'\ 4''\cdot 09$: 24^h :: any portion of mean time to its equivalent in sidereal time.

To find the Eccentricity of the Earth's Orbit.

HAVING the greatest equation of the centre, we can easily find the eccentricity of the earth's orbit by the following proportion :

As the diameter of a circle in degrees,
Is to the diameter in equal parts;
So is the greatest equation of the centre in degrees,
To the eccentricity in equal parts.

Example.—The greatest equation of the centre, is $1^\circ\ 55'\ 33''\cdot 1925833$, and the circumference of a circle whose diameter is 1, is $3\cdot 1415926$; then, $3\cdot 1415926$: 1 :: 360° : $114^\circ\cdot 5915609$ equal the diameter; and $114^\circ\cdot 5915609$: 1 :: $1\cdot 9258333$: $\cdot 0168061$ eccentricity. Hence

$$1+0\cdot 0168061=1\cdot 016806,\text{ the aphelion distance; and}$$
$$1-0\cdot 016806 = \cdot 983194,\text{ the perihelion distance.}$$

The eccentricity of the earth's and moon's orbit may also be found by observing the variations of the apparent diameter of the sun and moon during a complete revolution, (by a micrometer) their distance from the earth being inversely proportional to the angle which they subtend.

The ratio of their greatest and least diameters is a measure of the

relation between their greatest and least distances, and consequently enables us to ascertain the eccentricity of their orbits.

Thus, if the diameter of the sun be found to measure 32′ 35″·6 when the earth is in one part of her orbit; and 31′ 31″ when in the opposite point (which is found to be the case on the 1st January and 1st July) then will the ratio of the diameter of the orbit be to the eccentricity as $32'35''\cdot6 - 31'31'' = 1'4''\cdot6$ and $\frac{64''\cdot6}{2} \div \frac{32'35''\cdot6 + 31'31''}{2}$

$\frac{323''}{19233''} = \cdot0168$ nearly what it was found to be above.

This method is more liable to error than the first.

To find the Time and Place of the Sun's Apogee.

The apogée is that point of the orbit which is farthest from the focus in which the sun is placed; this problem is therefore no more than to determine at what time the planet is farthest from the sun.

By the decrease of the sun's apparent diameter, we can have an idea when this happens, though other methods must be had recourse to, when we wish to determine it accurately; one of these is as follows: On the day of two successive apsides, observe the sun's place and the time. Then if the interval between those times be equal to the half of 365^d 6^h 15′ 28″, and the difference of the sun's places be equal to the half of 360° 1′ 6″ (the space he describes in the above time), the observations were made when the sun was in the apsides.

But if those observed intervals of time and place differ from the above halves, take the difference between the interval of place and 180° 0′ 33″. Then to the daily motion of the sun in apogée (which is 57′ 12″) the said difference and 24^h find the proportional time: which proportional time and difference being applied to the time and places of the apogéon observation, gives a time and place when it is 180° 0′ 33″ distant from the observed perigeon place: now, if the interval of these times be 182^d 15^h 7′ 44½″ the times and places of the apsides are known.

But if the interval of time differs from 182^h 15^d 7′ 44½″, say, as the difference between the perigeon and apogeon daily motions, is to the daily motion of the apogée, so is the difference of the interval of time to a second correction of the time of the apogée; which applied to the apogeon time, corrected as above, will give the true time of the sun apogée. Also, to the last correction of time, find the proportional motion of the sun's apogée, and apply it to the last corrected place of the apogée, and the true place of the apogée will be obtained.

At any Given Time to find the Sun's Mean Anomaly.

The time when the sun passes his aphelion being accurately ascertained, the mean anomaly at any time may be found, by multiply-

ing the sun's daily mean motion (which is 59′ 8″) by the number of days, and parts of a day, which he is past his aphelion.

Or, as the time of a tropical revolution, or solar year, is to the interval between the aphelion and given time, so is 360° to the degrees of mean anomaly.

Or, from the tables of mean motions find the sun's mean motion for the given time, and this will be the mean anomaly.

If the earth's orbit were circular, the sun's true place at any time would be the same as shown by the tables of his mean motion; or the mean and true anomaly would always be the same. But the earth moving in an elliptical orbit, its true anomaly will differ from its mean, in every part of her orbit, except when she is in her perihelion and aphelion, where they coincide.

To find the Sun's true Anomaly

HAVING the sun's mean anomaly, and the dimensions of the earth's orbit, the eccentric anomaly may be found by the following analogy:

As the aphelion distance
Is to the perihelion distance;
So is the tangent of half the mean anomaly
To the tangent of an arc A;

which arc being added to half the mean anomaly, gives the eccentric anomaly.

The sun's eccentric anomaly, and the dimensions of the earth's orbit being known, to find the true anomaly.

Rule.—As the square root of the aphelion distance
Is to the square root of the perihelion distance;
So is the tangent of half the eccentric anomaly
To the Tangent of half the true anomaly.

To find the mean Anomaly from the true being given.

Rule.—As the square root of the perihelion distance
Is to the square root of the aphelion distance;
So is the tangent of half the true anomaly
To the tangent of half the eccentric anomaly.

And, As radius is to the sine of the eccentric anomaly,
So is the degrees in an arc equal in length to the eccentricity;
To the degrees, &c. in the arc of correction, which being added to the eccentric anomaly, gives the mean anomaly.

Greatest equation of the centre		1° 55′ 38″
Eccentricity in parts	. .	·01682
Aphelion distance	. .	1·01682
Perihelion distance	. .	·98318

The logarithm of the ratio of the square root of the aphelion distance to the perihelion distance is 0·00731; therefore, if this constant log. be added to the log. tangent of ½ the true anomaly, it will give the tangent of ½ the eccentric anomaly.

And in the second proportion, the arc equal in length to the eccentricity 1682, is also a constant quantity, which may be found as follows: 100000 : 1682 :: 57°·29578 : 0°·96375 eccentricity, the log. of which is 9·98396, this added to the log. sine of the eccentric anomaly, abating 10 from the indices of the sun, gives the log. of an arc, the degrees, minutes, and seconds of which being added to the eccentric anomaly, gives the mean anomaly.

To find the Distances of the Heavenly Bodies.

THE distances of the heavenly bodies are found by discovering their horizontal parallaxes. The horizontal parallax of any body has already been explained to be, the angle under which the semidiameter of the earth would appear if it were seen from that body, and this is found out by various methods.

The parallax most wanted is that of the sun, by which his distance from the earth may easily be found; and from knowing *this*, the true distances of the planets from the sun may be otained from their relative distances, by the second law of Kepler.

Before the year 1761, the sun's parallax was always stated at 12½″; but in the above year, Dr. Halley discovered, by the transit of the planet Venus across the sun's disc, that his parallax was only 8⅔″ which makes his distance much greater than it was then supposed to be.

Having his parallax, his distance is found by this analogy.

As Tan. Parallax	. .	8″·6	= 5·6227666
Is to Earth's semid.	.	1	= 0
So is Rad.	. . .	90°	= 10·
To dis. in Semid. Earth		23835·1	= 4·3772334
Semid. Earth	. . .	3981	= 3·6000000
Dist. in Eng. miles		94·897·172	= 7·9772334.

The nearer any object is to the earth the greater will be its parallax; for the semidiameter of the earth must then appear under a greater angle. The moon being much nearer the earth than the sun, her parallax is much greater: at a mean rate it amounts to 57′ 26″, Her distance may be found by the same analogy as that given for the sun above, which will be found to be about 240,000 miles.

When any object is in the horizon, its parallax is greatest, and it diminishes as the altitude of the object increases. In the zenith it will have no parallax.

In most calculations, where the moon is concerned, it becomes necessary to find her parallax in altitude; this is done by saying,

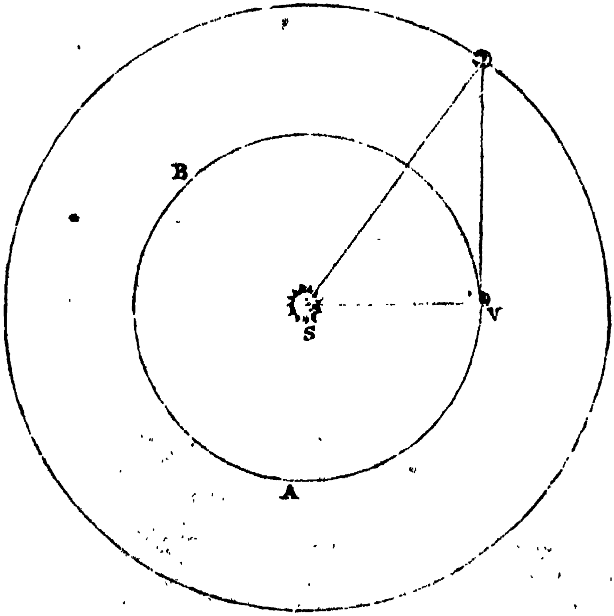
As radius is to the horizontal parallax, so is the cosine of the altitude to the sine of the parallax in altitude.

In the same manner may the distance of any planet be found, if its parallax be known.

As the fixed stars have no sensible parallax, their distance can only be guessed at; for though Dr. Bradley made many attempts, with the best of instruments, to discover the parallax of the star γ Draconis, he never could find its parallax to amount to a single second.

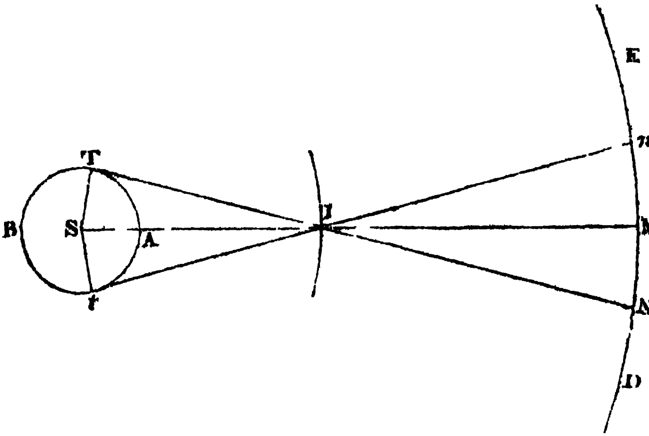
The distances of Mercury and Venus may also be determined by their greatest elongations from the sun.

Thus, let S be the sun, T the earth, A V B the orbit of Venus, which suppose perfectly circular, let V represent the place of Venus, at her greatest elongation, and join V T; then in the triangle S T V, right-angled at V, the angles, viz. the angle V, and the angle S T V, the greatest elongation, and the side S T the earth's distance from the sun are known, therefore, the side S V, Venus's distance from the sun may be found, and the side T V, Venus's distance from the earth, may also be found by plane trigonometry.



The distances of the superior planets may be determined by their retrograde motions, and such of them as have satellites, by the eclipses of those satellites.

Let I represent Jupiter, S the sun, and E the earth, join S I, and produce it to M; then I M is the axis of his shadow, the position of which is determined by the eclipses of the satellites, and shews his heliocentric place. Join T I and produce it to N, which will be the place of Jupiter when viewed from the earth. The difference of these places gives the angle N I M, or T I S; the elongation of Jupiter when viewed from the earth at T; or the angle I T S is easily found by observation, consequently all the angles in the triangle T I S are known, and also the side S T, the distance of the earth from the sun; therefore the sides S I and T I may both be found, and thus the distance of Jupiter from the sun or the earth is obtained.



In the same figure, let I represent any of the superior planets, or any remote object of the system A, the point where the earth passes between the sun S and object I, and let I T be a tangent drawn from I to the earth's orbit, which suppose to be circular: then the earth being at A, the object I will appear in the same place both to the earth and sun; but when the earth comes to T, supposing I to have no motion, it will appear to the earth to have gone backward by the arc that measures the angle T I S, or the angle which the earth's distance from the sun subtends at the object I; and this angle being determined by observation, its sine will be to radius, as S T, the distance of the earth from the sun, to S I, the distance of the object from the sun; or as its co-sine to T I, the distance of the object from the earth.

It is in this manner that the earth's annual parallax is used by astronomers instead of the diurnal, in finding the distances of remote objects not belonging to the solar system; the semidiameter of the earth being so small in comparison of those distances that they have found it necessary to substitute the semidiameter of her orbit instead of it, which is called the annual parallax.

To find the Periodic Time of a Planet.

THE times in which the planets perform their revolutions about the sun are known by observation; therefore, having the distance of any one of them from the sun, the distance of the others may be found by Kepler's law. Thus, suppose the distance of the earth from the sun to be 1, and it is required to find the distance of Mercury;

$$365\tfrac{1}{4}^2 : 1^3 : 88^2 :: \sqrt[3]{05805} = \cdot 87;$$ and so of the others.

To find the Time of the Sun's Rising and Setting.

Rule.—To the tangent of the latitude of the place, add the tangent of sun's declination; the sum, rejecting 10 from the index, will be the logarithm co-sine of an arch, which reduced to time, at the rate of 15° to an hour, will be the time of the rising, when the declination is of the same name with the latitude; but the time of setting, when it is of a different name.

Required the time of the sun's rising in latitude 52° 12′ N., on the 4th of May?

The sun's declination on the 4th of May is 15° 54′ N. which is therefore of the same name with the latitude. Hence, in the present example:

Tan. 15° 54′	Log. 9·454628
Tan. 52 12	Log. 10·110318
Co-Sine 68° 27′	Log. 19·565046

Now, 68° 27′ converted into time is 4 hours 34 minutes nearly; which is the time of the sun's rising on the 4th of May, at latitude 52° 12′ N.

To find the Time of a Planet Rising and Setting.

IN the same manner may half the time of a star or planet's continuance above the horizon be found; but in order to find the time of its rising, this time must be subtracted from the time of its passing the meridian; and to find the time of its setting, it must be added to the time of its passing the meridian.

As the time of a planet's passing the meridian can easily be obtained from an ephemeris, and the time of its half continuance above the horizon by the above rule, it is unnecessary to give an example of computing the time of a planet rising or setting.

The time of a fixed star's rising or setting is found exactly in the same manner as that of a planet.

To find the Time of a Star or Planet's passing the Meridian on any Day of the Year, &c.

Rule.—From the right ascension of the star* subtract the right ascension of the sun, for the given day, and the remainder will be the approximated time of the star's passing the meridian. If the star's right ascension be less than the sun's, it must be increased by twenty-four hours.

When the time of the star's passage over the meridian is less than twelve hours, the time is P. M.; when greater, it will be as many hour after 12 P. M. of the given day.

The approximate time of a planet's passing the meridian may be found in the same manner, if its right ascension be known.

To find the Real Magnitudes of the Planets.

HAVING found, by observation, the apparent diameters of the planets, either at their greatest or least distance from the earth, and knowing previously the distance of the earth from the sun, and also the distance of the planets, their real magnitudes may be found by a simple calculation. Since the apparent diameters of distant bodies vary inversely as their distances, it is easy to ascertain what must be the apparent diameter of each of the planets viewed from the sun; or, what is better, the apparent diameter of each of the planets, viewed at a distance equal to that of the sun from the earth.

Example.—Venus's mean distance from the sun is known to be about 68,000,000 miles, and the earth 95,000,000 miles; *ergo*, when Venus is in her inferior conjunction, or nearest to the earth, she is only 27,000,000 million miles from the earth (for 95—68=27). We know, from observation, Venus's apparent diameter in this position is 60″; *ergo*, 27 : 60″ : : 95 : 17″ nearly diameter of Venus, viewed at as great a distance from the sun as the earth, and the apparent diameter of the earth at the sun is known to be 17″·5 (double 8″·73 the parallax); *ergo*, as 17″·5 : 7912^{m} : : 17″ : 7686 miles, the real diameter of Venus. In like manner, Jupiter in opposition has an apparent diameter of 48″, his mean distance about 490,000,000 miles; *ergo*, at that time his distance from the earth is 395,000,000 miles; *ergo*, 395^{m} : 48″ : : 95^{m} : 199″, the apparent diameter of Jupiter at the distance of the earth from the sun.

To find his real diameter, we have only to say, 17″·5 : 7912^{m} : : 199″ : 89160^{m}.

The apparent diameter of the sun, as seen from the earth, is about 32′ or 1920″; *ergo*, 17″·5 : 7912^{m} : : 1920″ : 870,000^{m} nearly. The real diameter of the moon and the other planets may be found in a similar manner: and hence their bulks may be easily calculated as follows:

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* See Table, page 16.

The sun, at his mean distance from the earth, subtends an angle of 32′ 12″ = 1932″, and the earth at the sun $17\frac{1}{3}$″, therefore the sun's diameter is to the earth's diameter as 1932″ to $17\frac{1}{3}$″, or as $111\frac{1}{3}$ to 1; and as spheres are to each other as the cubes of their diameters, the bulk of the sun will be to the bulk of the earth as the cube of $111\frac{1}{3}$ to the cube of 1, or as 1380160 to 1. The earth's diameter, as seen from the moon, subtends an angle of double the moon's horizontal parallax, which being taken at 57′ 26″, or 3446″, the earth's must be 1° 54′ 52″, or 6892″; when the moon's horizontal parallax is as here stated, her diameter subtends an angle of 31′ 2″ = 1862″; therefore the earth's diameter is to that of the moon's as 3146′ to 1862″, or as 3·7 to 1; and her bulk will be to the moon's as 49·4 to 1.

In this manner may the bulk of any of the planets be found: by first finding what angle the planet subtends from the earth, and then comparing its diameter with the earth's diameter.

Note.—As Venus is seen, sometimes, on the sun's disc, which is at the time she is in her inferior conjunction, or nearest to the earth, it affords an excellent opportunity of measuring her apparent diameter.

The elements of the planets are—1st. long. ascending node; 2d. eccentricity of orbit; 3d. mean longitude, 1st January; 4th. mean longitude perihelion; 5th. secular variation of perihelion; 6th. inclination of orbit; 7th. sidereal revolution; 8th. mean distance.

Method of finding the Mass of Matter in the Sun and Planets.

LET F and f denote the forces by which two bodies revolve in circles, whose radii are D and d in the periodic times P and p; then by the theory of central forces (Dynamics) $F : f :: \frac{D}{P^2} : \frac{d}{p^2}$.

Now in the case of the sun and planets, the force F is the amount of the deflections of the revolving body to all the particles in the central body, which, putting M for the mass of matter in that body, will be expressed by $\frac{M}{D^2}$, and similarly putting m for the matter in the central body towards which the other body gravitates at the distance d, $\frac{m}{d^2}$ therefore, $\frac{M}{D^2} : \frac{m}{d^2} :: \frac{D}{P^2} : \frac{d}{p^2}$ and consequently $M : m :: \frac{D^3}{P^2} : \frac{d^3}{p^2}$. Hence it appears, that the mass of matter in the bodies that compose the solar system are directly as the cubes of the mean distances of any bodies which revolve about them, and inversely as the squares of the times in which the revolutions are performed.

The application of the above theorem to determine the quantity of matter in the sun, taking the quantity of matter in the earth as unity.

The sun's distance in miles . .	93726900
The moon's distance	240144
Earth's revolution in sidereal days .	365·25
Moon's sidereal revolution . . .	27·322

Then by the formula:

$$\frac{240144^3}{27\cdot322^2} : \frac{93726900^3}{365\cdot25^2} :: m = 1 : M = \text{the matter in the sun}$$

$$\text{Therefore } M = \frac{93726900^3 \times 27\cdot322^2}{365\cdot25^2 \times 240144^3} = 332660$$

But this must be increased about $\frac{1}{70}$th, because the moon is here supposed to revolve about the centre of the earth, whereas she really moves about their common centre, and on this account the gravitation of the earth is estimated greater than it ought to be.

Thus increased, the quantity of matter in the sun may be reckoned at 337422 times that of the earth.

However this cannot be considered as very accurate, as the sun's distance from the earth is uncertain, it being deduced from his horizontal parallax, which is said to be only about 8′ 7 or 8 8, and an error of *one tenth* of a second in the parallax will produce an error of $\frac{1}{30}$ of the whole, for the error will vary in a triplicate proportion.

In the same manner may Jupiter be compared with the earth; by comparing the gravitation of his nearest satellite with that of the moon. By a calculation similar to the above, it appears that Jupiter contains 313 times more matter than the earth. From the periodic times and distances of the satellites of Saturn and Uranus, may also be estimated the forces by which they gravitate; and hence it is found, by calculation, that the former planet contains 103 times more matter than the earth, and the latter 17 times as much.

The quantity of matter in those planets that have no satellites can only be guessed from the effect they produce in disturbing the motions of the other planets. The quantity of matter in the moon, however, may be determined with greater certainty, by comparing together the influence of the sun and moon in producing the tides, and the precession of the equinoxes. Hence it is found that the moon is about $\frac{1}{70}$ of the earth.—The quantity of matter in each of the planets has already been stated at page 145 of this Work, to which the reader may refer for more information on this subject.

To determine the Longitude of Places on the Earth.

THIS is a problem of such great difficulty in practice, that, although the efforts of some of the greatest mathematicians in Europe have been directed towards the invention of easy, practicable methods, yet none has been hitherto discovered that is not liable to errors; these errors, it must be remarked, are not to be ascribed entirely to the theory, (which is, at least, with respect to several of the methods, accurate,) but to the practice, particularly when the observations for determining the longitude are taken at sea. Still, however, when a comparison is formed between the modern methods of solving this problem, and those which were practised two centuries ago, it will appear that very considerable advances have been made towards a perfect solution; and these are probably, in great measure, to be attributed to the very handsome rewards which have been offered by

commercial nations to those who should propose the most accurate and practicable way of attaining so desirable an end.

It may seem a matter of astonishment, that this question, which is probably the most interesting that ever engaged the human attention, is little more than to be able to tell what o'clock it is elsewhere; for the longitude is found by the comparison of local or relative time; and as the hour is easily found at the place of observation by altitudes, the only difficulty is, to find the time at the same instant at some other place whose longitude is known. Now as the sun, in his daily course, passes over 360 degrees of longitude in 24 hours, he passes over 15 degrees in one hour, and over any other space in this proportion; and therefore if the difference in time between any two places be known, the difference of longitude is thence determined.

Hence, if a perfect time-keeper could be constructed, it would obviate all difficulty on this subject, and render the longitude as simple a problem as the latitude; for such an instrument being set to the time of any place whose longitude is known (suppose to that of Greenwich Observatory, from whence we reckon our longitude) it would preserve this time in all other parts of the world; and, by comparing this chronometer with a clock or watch properly regulated for the place of observation, the difference would show the longitude.

Notwithstanding the great degree of perfection to which time-keepers have been brought, they cannot be supposed such infallible guides to the longitude as the heavenly bodies: the advantage the former have is, that of being at all times most easily consulted; but the prudent mariner will not trust to chronometers alone, though he must use them as auxiliaries to his astronomical calculations; for such delicate and complicated pieces of mechanism will be ever more or less liable to be affected by the violence of motion, or the vicissitudes of season and climate, and, like all other productions of human art, must be subject to accident, disorder, and decay: whereas the heavenly bodies are unchangeable; these only are the unerring time-keepers which exibit a true species of *perpetual motion*.

There are various methods of finding the longitude by celestial observations, but all proceed upon the same principle, or tend to the same object, which is to tell the time at Greenwich Observatory, and this compared with the time at the place of observation, shews the distance east or west from Greenwich, and of course shews the longitude of that place.

First method: By the sun's declination.—Find the declination of the sun at noon, from observations made upon him either at the meridian, or three or four hours from it: take the difference between this computed declination, and that for the noon of the same day at Greenwich, as shewn by the Ephemeris; from which take likewise the daily difference of declination at that time, then employ the following analogy: As the daily difference of declination, is to the difference above found, so are 360° to the difference of longitude. But here a small error in the computed declination, will cause a very considerable one in the difference of longitude; and as such an error must inevitably arise from considering the change of declination, during a day, as regular, this method is not to be recommended in practice.

Second method: By the moon's culminating.—Seek in the Ephemeris for the time of the moon's coming to the meridian on the given day, and on the day following, and take the difference; take also the difference between their times of culminating on the same day, as found in the Ephemeris, and as observed; then say, as the daily difference in the Ephemeris, is to the difference between the times of southing found by the Ephemeris and by observation, so are 360° to the difference of longitude. Here the moon's motion is supposed to be uniform, which is not the case; therefore, since a small error in this respect, or in the time of the moon's culminating, may occasion a great error in the longitude, this method is no more to be recommended in practice than the former.

Third method: By the distance between the moon and a known fixed star, when both are on the meridian.—Let one observer take the altitude of the moon's centre when on the meridian (which may be done by taking the altitude of the upper or lower limb, and allowing for the semidiameter), and another the altitude of any such star in the zodiac as then happens to be on or very near the meridian. Now the right ascension of the moon will be equal to the right ascension of the star, if they were on the meridian exactly together; but if they are not on the meridian together, if their difference of culminating do not exceed eight or ten minutes, the right ascension of the moon may be found by adding or subtracting this difference to or from the right ascension of the star, according as the moon culminates after or before the star. Then, knowing the day of the month, with the moon's right ascension, examine the *Nautical Almanac*, and find, by proportion, at what time at Greenwich the moon had that right ascension. Take also the difference between the meridional altitudes of the moon and the star which is then on the meridian; this difference (when properly corrected for dip, refraction, and parallax) will be the difference of the declinations of the moon and star, whence, the declination of the star being known, that of the moon becomes known also. Then find, by means of the Nautical Almanac, at what time on the given day, the moon had this declination: if the time thus found agree either exactly or very nearly with the time deduced from the right ascension, take the difference between half the sum of them, and the time of the observation (determined by some of the methods before referred to), for the difference of longitude in time, whence the longitude in degrees, &c. may be found: but if the times thus deduced do not correspond tolerably accurately, recourse must be had to some of the following methods.

Fourth method: By eclipses of the moon.—These eclipses are seen at the same instant of absolute time in all parts of the earth: therefore, if in two or more distant places where an eclipse of the moon is visible, the times of the beginning or ending are carefully observed; as also the times when any number of digits were eclipsed; or, which is better, the times when the earth's shadow began to touch, or to leave any remarkable spot on the moon's face; then will the difference of the times when the observations of like kind were made, give the difference of longitude between the places of observation. Or, instead of comparing the observations at two different meridians, the

times of the beginning and end of the eclipse, as observed at the place the longitude of which is required, may be compared with the times of beginning and end at Greenwich, as given in the Nautical Almanac, and the longitude may be deduced from the difference of times as before: but the longitude thus found will not be so accurate as that determined by two observations, because of the inaccuracy of the lunar tables, and of the great difficulty of telling exactly the time of the first and last contact of the earth's shadow with the moon's limb.

Fifth method: By the eclipses of Jupiter's satellites.—The eclipses of Jupiter's satellites afford one of the readiest, and for general practice one of the best, methods of determining the longitudes of places at land: and whenever Jupiter is to be seen,* they might be applied at sea, oftener than they would be wanted, if they could be observed with sufficient accuracy in a ship under sail. In order to find the longitude of a place at land by an eclipse of one of Jupiter's satellites, the following directions must be observed:—On the day preceding the evening on which it is proposed to observe the eclipse, note the time it will happen at Greenwich, as given in the Nautical Almanac. Let the estimated longitude of the place of observation be converted into time, and, if *eastward* of Greenwich, *added* to the time of the beginning of the eclipse, as given in the Nautical Almanac; but if the place be *westward*, *subtracted*; and it will give the time nearly when the eclipse is to be expected at that place. Begin to observe twenty or thirty minutes sooner than the time thus estimated, and let the instant when the eclipse begins or ends be noted, as shewn by a watch previously regulated to mean time at the place of observation: then the difference between this time and the Greenwich time, converted into degrees, will shew the longitude from Greenwich. If the time at Greenwich be *less* than the time observed, the longitude is *east*; otherwise it is *west*. The best eclipses for finding the longitude are those of the first satellite, because its theory is most accurately settled; but it should be observed, that its *emersions* are not visible from the time of Jupiter's conjunction with the sun to the time of his opposition; and the *immersions* are not visible from his opposition to his conjunction.

A sixth method, is by the difference between the observed times of the moon and a fixed star passing the meridian of each place. But this method is attended with very considerable trouble in the calculation, and is not more accurate than the methods already noticed.

The *last method* we shall notice is that of observing the distance between the moon and the sun, or a fixed star. This is one of the most accurate methods which can be employed, and is peculiarly adapted for determining the longitude at sea. It is, therefore, the only astronomical method to which seamen have recourse to for this

* An eclipse will be visible in any place, if Jupiter be 8° or more above the horizon, and the sun as much below it: whether this will or will not be the case at any place where the observation is intended to be made, may be readily found with sufficient accuracy by a celestial globe.

important purpose, but our limits will not permit us to enlarge farther upon it.

Variation charts have also been recommended; but they cannot be depended upon for any length of time, as the *needle* is constantly changing its direction, and the law of its variation is still a secret.

Explanation and Use of the Nautical Almanac of Ephemeris.

THIS National Almanac is chiefly intended for nautical purposes, but it is of the greatest use in all astronomical calculations. It was begun in 1767, under the direction of the Board of Longitude, on the recommendation of Dr. Maskelyne, who had the immediate conducting of it for many years.

All the calculations of the Ephemeris, except those of the eclipses of Jupiter's satellites, are made according to the apparent time by the meridian of the Royal Observatory at Greenwich; and the sun's, planets', and moon's places, with the particulars depending on them, are computed to the instant of apparent noon, or that of the sun's centre passing the meridian of Greenwich.

The day is here supposed, according to the method of astronomers, to begin at noon, or twelve hours later than the civil day of the same denomination, and to be counted up to twenty-four hours, or the succeeding noon, when the next day begins. Thus the day of the month and the hour of the day are the same in this method as in the civil account at noon, and from noon till midnight; but from midnight till noon they differ.

There are *twelve* pages for every month. The first column of the first page of each month contains the day of the week expressed concisely by the initial letter or letters; the second the day of the month; the third column exhibits the Sundays and Festivals of the Church of England, and other remarkable days; the last column shows at top the moon's phases, or the times of new and full moon, and of the first and last quarter or two quadratures with the sun; beneath are contained miscellaneous phenomena; namely, eclipses of the sun and moon, and occultations of planets or fixed stars not less than the "fourth" magnitude, by the moon, which can be occultations any where on the globe, between the latitudes of 60° north and 40° south; the entrance of the sun into the several signs, and any other remarkable phenomena.

The stars are expressed by Bayer's characters of reference. The conjunction of the moon or a planet with a star is denoted by prefixing the character of the moon or planet to that of the star, the time of the conjunction being placed immediately before. The case is the same with respect to the occultation of a star or planet by the moon, only this is further distinguished by the addition of im. or immersion, to signify the disappearance behind the moon: and em. or emersion, to signify the re-appearance of the same. Thus $8^d\ 16^h\ 22'$ ☽ ϑ ♑, signifies that the moon will be in conjunction with the star ϑ ♑ on the eighth day at $16^h\ 22'$, exclusive of parallax; and $10^d\ 9^h\ 14$ im. of ε ♊; $10^d\ 10^h\ 23'$ em. signifies that the moon will eclipse ε ♊ on

the 10th day, the immersion being at 9^h 14, and the emersion at 10^h 23 apparent time at Greenwich.

The occultations set down are only those visible at Greenwich; the circumstances of which will commonly not differ very widely in most parts of the kingdom; but in very distant places they will differ very much, owing to the change of the moon's parallax, or it may become no occultation at all. The same may be said of eclipses of the sun.

The two first columns of the second page of the month contain the day of the week and month, as before; next follow the sun's longitude, right ascension in time, declination, and the equation of time with its difference from day to day.

To find the sun's longitude at any time different from noon, proportion must be made according to its daily increase: saying, as 24^h is to the hour from noon reckoned by the meridian of Greenwich, so is the daily variation of the sun's longitude to a fourth number; which added to the sun's longitude at the preceding noon, gives the true longitude at the given time.

If the time given be that of a meridian different from Greenwich, it must be first reduced thereto, by adding or subtracting the difference of longitude turned into time at the rate of one hour to 15°.

The sun's longitude serves also to compute the aberration of the fixed stars and planets.

The sun's right ascension in time is useful to the practical astronomer in regular observatories, who adjusts his clocks by sidereal time. It is also useful to him for converting apparent into sidereal time; as suppose that of an eclipse of Jupiter's satellites, in order to know at what time it may be expected to happen by his clock. For this purpose the sun's right ascension at the preceding noon, together with the increase of right ascension from noon, must be added to the apparent time of the phenomenon set down in the Ephemeris.

The sun's right ascension in time serves also to compute the apparent time of a known star passing the meridian: thus, subtract the sun's right ascension in time at noon from the star's right ascension in time, the remainder is the apparent time of the star's passing the meridian nearly; from which the proportional part of the daily increase of the sun's right ascension for this apparent time from noon being subtracted, leaves the correct time of the star's passing the meridian.

The sun's declination is necessary to find the latitude, whether at sea or land, from his meridian altitude observed. It is also necessary to calculate the apparent time from an observed altitude of the sun at a distance from the meridian, the latitude being given; or to compute the time of the sun's setting or rising, which, though a less accurate method than the former of obtaining the time, may yet be useful when that cannot be had. For any of these purposes the sun's declination must be found to the time given nearly, reduced to the meridian of Greenwich, making proportion according to the daily increase or decrease, in like manner as was shown with respect to the sun's longitude.

The equation of time is a correction, which added to, or subtracted from the apparent time (according to its title at the top of the column)

gives equated or mean time, or that which should be shown by a good clock or watch.

The equation of time being set down in the Ephemeris for noon at Greenwich, proportion must be made according to the daily difference, to find what it should be at any given time reduced to the same meridian, as in the preceding articles. The last column of this page, containing the daily differences of the equation, is designed for this purpose.

But when time-keepers are used at sea, the apparent time deduced from an altitude of the sun must be corrected by the equation of time, and the mean time found compared with that shown by the watch; the difference will be the longitude in time from the meridian by which the watch was set, as near as the going of the watch can be depended upon.

The time of the sun's semidiameter passing the meridian, page 3d, serves to reduce an observation of a transit of the preceding or subsequent limb over the meridian to that of the centre, when only one was observed. It signifies a portion of apparent time, or even mean time, the difference being absolutely insensible upon so small an interval.

From the time of the sun's semidiameter passing the meridian may also be found the time of its passing the horizontal or vertical wire of a quadrant or sextant, which on some occasions may have its use.

The semidiameter of the sun is necessary to reduce the observed altitude of his upper or lower limb to that of the centre; also to reduce the observed distance of the moon's nearest limb from the sun's nearest limb to the distance of the centres. It is also useful to astronomers to verify or ascertain the exactness of the scale of their micrometers, by comparison with the measure of the sun's horizontal diameter.

The hourly motion of the sun is useful in computing solar and lunar eclipses. The logarithm of the sun's distance is useful in the calculation of the places of the planets and comets. The place of the moon's node signifies its mean longitude, and is necessary for finding the equation of the equinoctial points both in longitude and right ascension, the equation of the obliquity of the ecliptic, and the deviations of the fixed stars in right ascension and declination.

The eclipses of Jupiter's satellites are set down on the lower part of page 3d, and to mean time. They are well known to afford the readiest, and for general practice the best method of settling the longitudes of places at land; and it is by their means principally that geography has been so much reformed since the invention of telescopes, and the construction of tables for calculating the time of their happening.

The eclipses of Jupiter's satellites are observed by astronomers at land, as well in order to provide materials for improving the theories and tables of their motions, as for the sake of comparison with the corresponding observations which may be made by persons in different parts of the globe, whereby the longitude of such places will be accurately ascertained. It is indeed to be lamented that persons, who visit distant countries, are not more diligent to multiply observa-

tions of this kind; for want of which, the observations made by astronomers in established observatories lose half their use, and the improvement of geography is retarded.

The eclipses, carefully calculated and set down in the Ephemeris, will serve to advertise them and observers in general of the times when they should attend to these observations.

The immersions signify the instant of the disappearance of the satellite by entering into the shadow of Jupiter; and the emersions signify the first instant of its appearance at coming out of the same. They generally happen when the satellite is at some distance from the body of Jupiter, except near the opposition of Jupiter to the sun when the satellite approaches nearer to his body. Before the opposition of Jupiter to the sun, the immersions and emersions happen on the west side of Jupiter, and after the opposition on the east side; but if an astronomical telescope be used, which reverses objects, the appearance will be directly the contrary. Before the opposition, the immersions only of the first satellite are visible; and after the opposition, the emersions only. The same is generally the case with respect to the second satellite; but both the phenomena of the same eclipse are frequently observable in the two outer satellites. The immersions and emersions, marked with an asterisk in the Ephemeris, are those visible at Greenwich.

The immersion or emersion of any satellite being carefully observed in any place according to mean time, the longitude from Greenwich is found immediately, by taking the difference of the observation from the corresponding time shewn in the Ephemeris, which must be turned into degrees, &c. and will be east or west of Greenwich, as the time observed is more or less than that of the Ephemeris.

Example.—Suppose an emersion of the first satellite should be observed at the Cape of Good Hope, April 16, 1805, at 13^h 25′ 35″ mean time; the time by the Ephemeris being 12^h 12′ 2″, the difference is 1^h 13′ 33″, whence the longitude of the Cape should be 18° 23′ 15″ east of Greenwich, because the time supposed to be observed at the Cape is more than that of the Ephemeris.

The longitudes and latitudes of the planets, page 4th, serve to show where to look for them in the heavens, to enable persons less skilled to distinguish them from the fixed stars. They also show when they are in the most important points of their orbits, where it is most material to observe them.

The 5th, 6th, 7th, 8th, 9th, 10th, and 11th pages of each month contain the moon's place, and all the circumstances relating to her motion and her distances from the sun and proper stars, from which her distances should be observed for finding the longitude at sea. For the sake of greater precision, the moon's longitude, latitude, right ascension, declination, semidiameter, horizontal parallax, with its proportional logarithm, are computed twice a day to noon and midnight, and may readily be inferred to any intermediate time with the greatest exactness.

The moon's longitude and latitude are used in computing the distances from the sun and stars contained in the four last pages of the month, as well as the appulses to stars pointed out in page 1st, and,

jointly with her parallax and semidiameter, are necessary for computing the eclipses of the sun and moon, and the occultations of fixed stars and planets by the moon. They also facilitate the calculation of the longitude of any place from an observed eclipse of the sun, or occultation of a star or planet by the moon. Or, if the longitude be well known, the parallax and semidiameter serve to deduce the moon's true place in the heavens from the observation, which, compared with that given by the Ephemeris, shows the error of the tables at the time. The moon's semidiameter and parallax are applied in correcting almost all observations of the moon. The proportional logarithms of the moon's parallax serve further to facilitate the calculations of parallaxes.

The moon's right ascension and declination are useful to compute her altitude at any time, particularly at the observation of her distance from the sun or a star, supposing it was neglected to be or could not be observed properly; which latter case may sometimes happen in the night. The moon's declination, with her semidiameter and parallax, serve for finding the latitude by the meridian altitude of her upper and lower limb observed at sea. The moon's right ascension and declination also serve to compute the time from her altitude observed at the observation of her distance from a star; whence the longitude may be inferred, though no altitude of the sun or a star was taken for regulating the time.

The distances of the moon from sun and fixed stars, contained in the 8th, 9th, 10th, and 11th pages of the month, are set down to every three hours of apparent time by the meridian of Greenwich, and are designed to prevent the necessity of a calculation by seamen and others who wish to determine the longitude by lunar observations.

The configurations of Jupiter's satellites, page 12th and last, exhibit the apparent positions of the satellites with respect to each other, and to Jupiter, at such an hour of the evening or night as they are most likely to be observed, and serve to distinguish the satellites from one another. Jupiter is distinguished by the mark ○, and the satellites by points with figures annexed; the figure 1 signifying the first satellite, 2 the second satellite, &c. When the satellite is approaching towards Jupiter, the figure is put between Jupiter and the point; and when the satellite is receding from Jupiter, the figure is put on the other side of the point. The satellites are in the superior parts of their orbits, or farthest from the earth, when they are marked to the right hand or west from Jupiter approaching him; or to the left hand or east of Jupiter receding from him; but are in the inferior parts of their orbits, or nearest to the earth, when they are marked to the right hand or west of Jupiter receding from him, or to the left or east of Jupiter approaching him. The cipher ○, sometimes annexed to the figure of the satellite towards the margin, signifies that it is invisible on the face of Jupiter; and the black mark ● signifies that it is [illegible] in Jupiter's shadow, or behind Jupiter [illegible]